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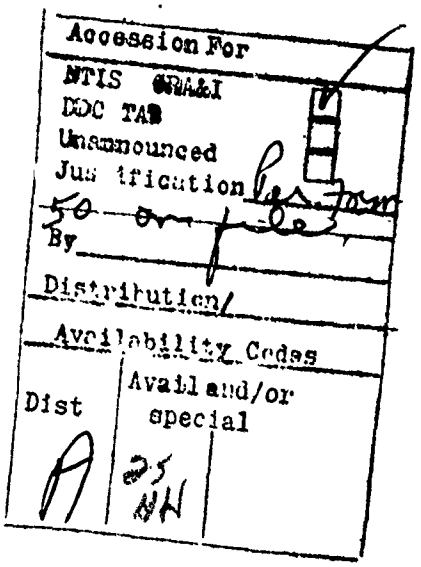

SECTION 13

VERIFICATION OF THE INFINITE IMPULSE RESPONSE FILTERS IN REAL-TIME

Two sets of data are presented here. Neither of them show the expected results, presumably because of the fixed time delay going through the filter.

Figure 13-1 shows the amplitude and phase portions of the transfer functions for the lowpass Butterworth filter. The magnitude portion of the transfer function is similar to that produced by the Burroughs 6700, but the phase portion of the transfer function does not agree at all. It resembles what might be expected from a lowpass analog filter.

Figures 13-2 and 13-3 show the results for the bandpass Chebychev filter. Here again, the results were different from what we expected after studying the Burroughs 6700 plots. Hopefully longer tests will verify the Burroughs 6700 results.

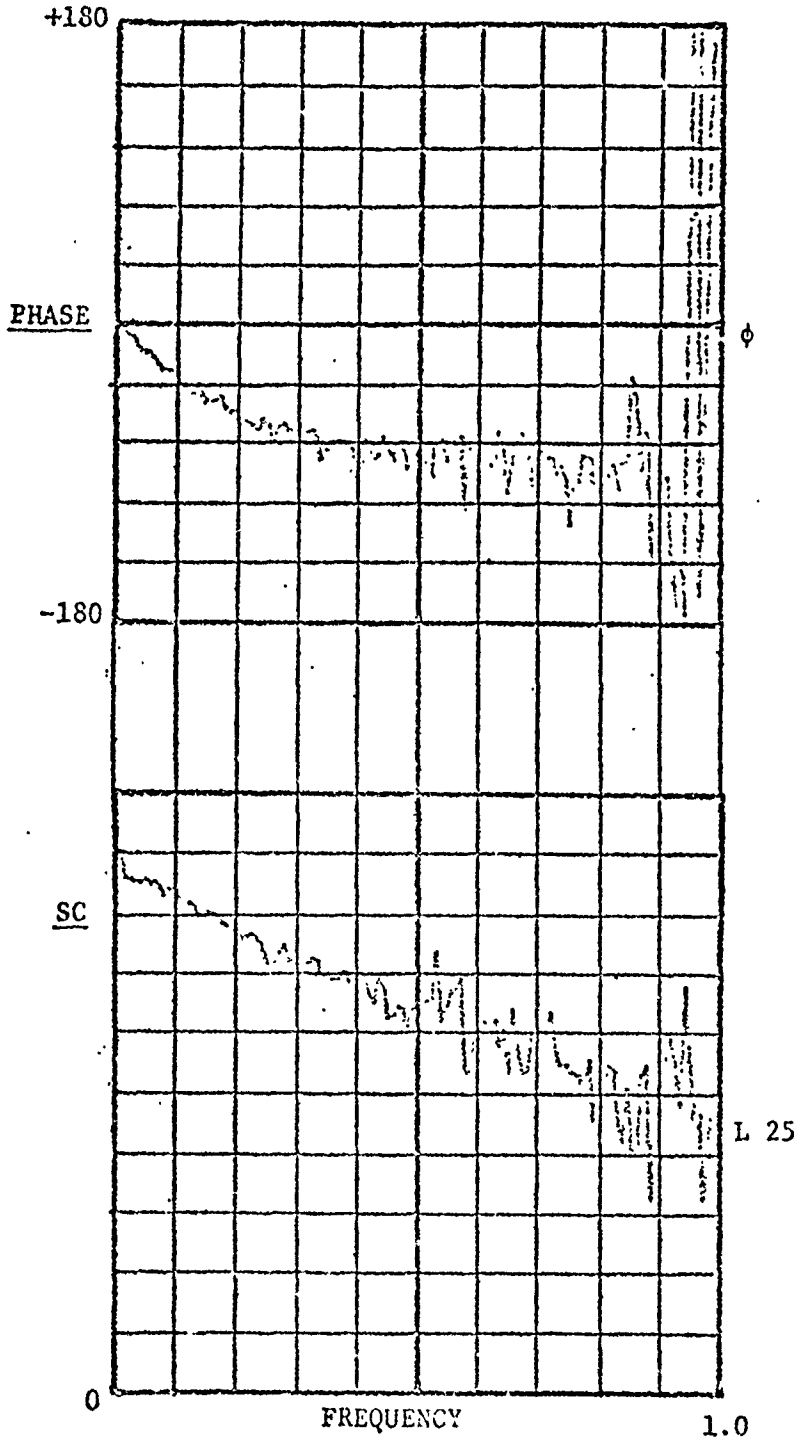

Figure 13-1 Transfer Function for Lowpass Butterworth.

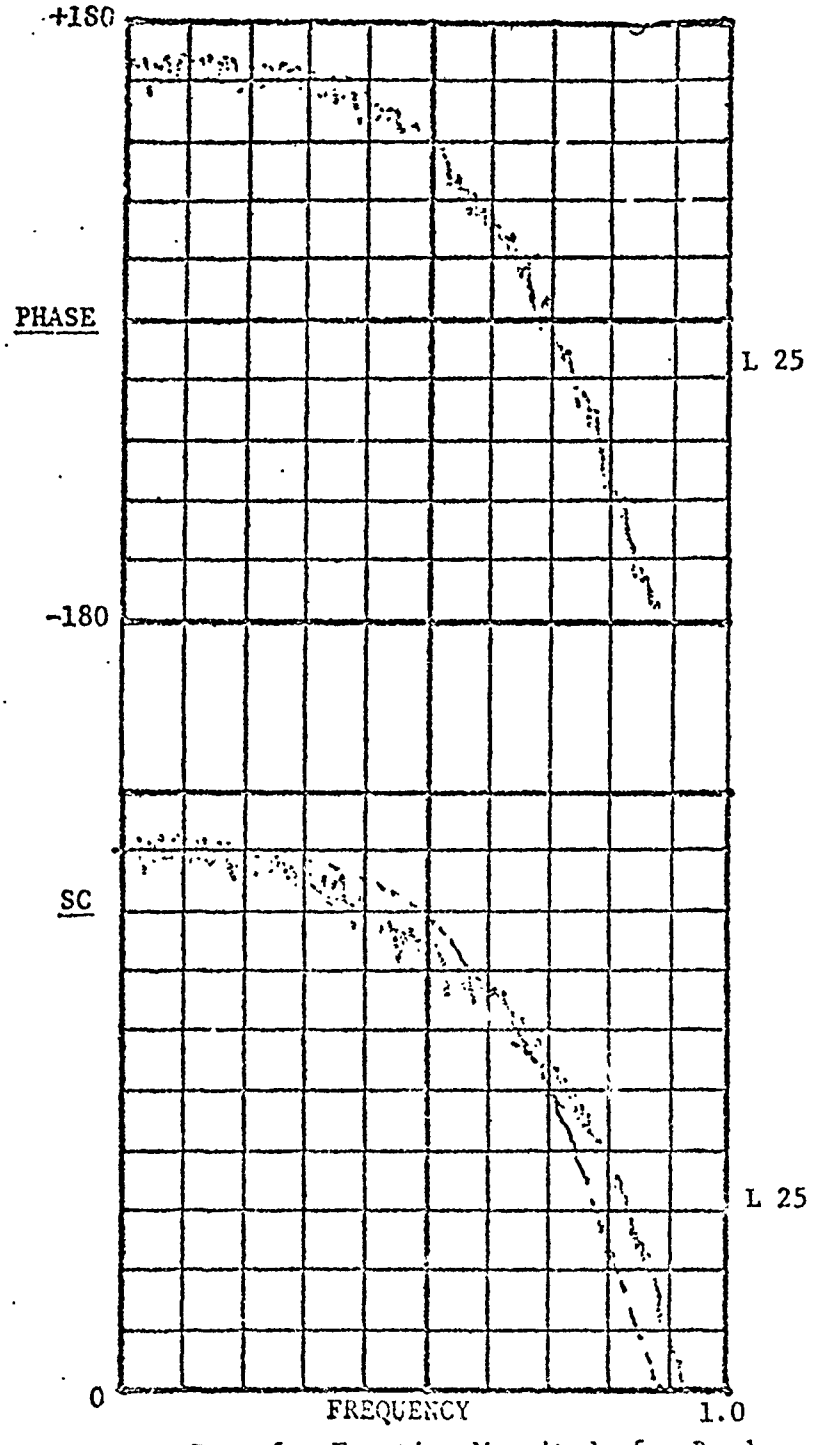

Figure 13-2 Transfer Function Magnitude for Bandpass Chebyshev.

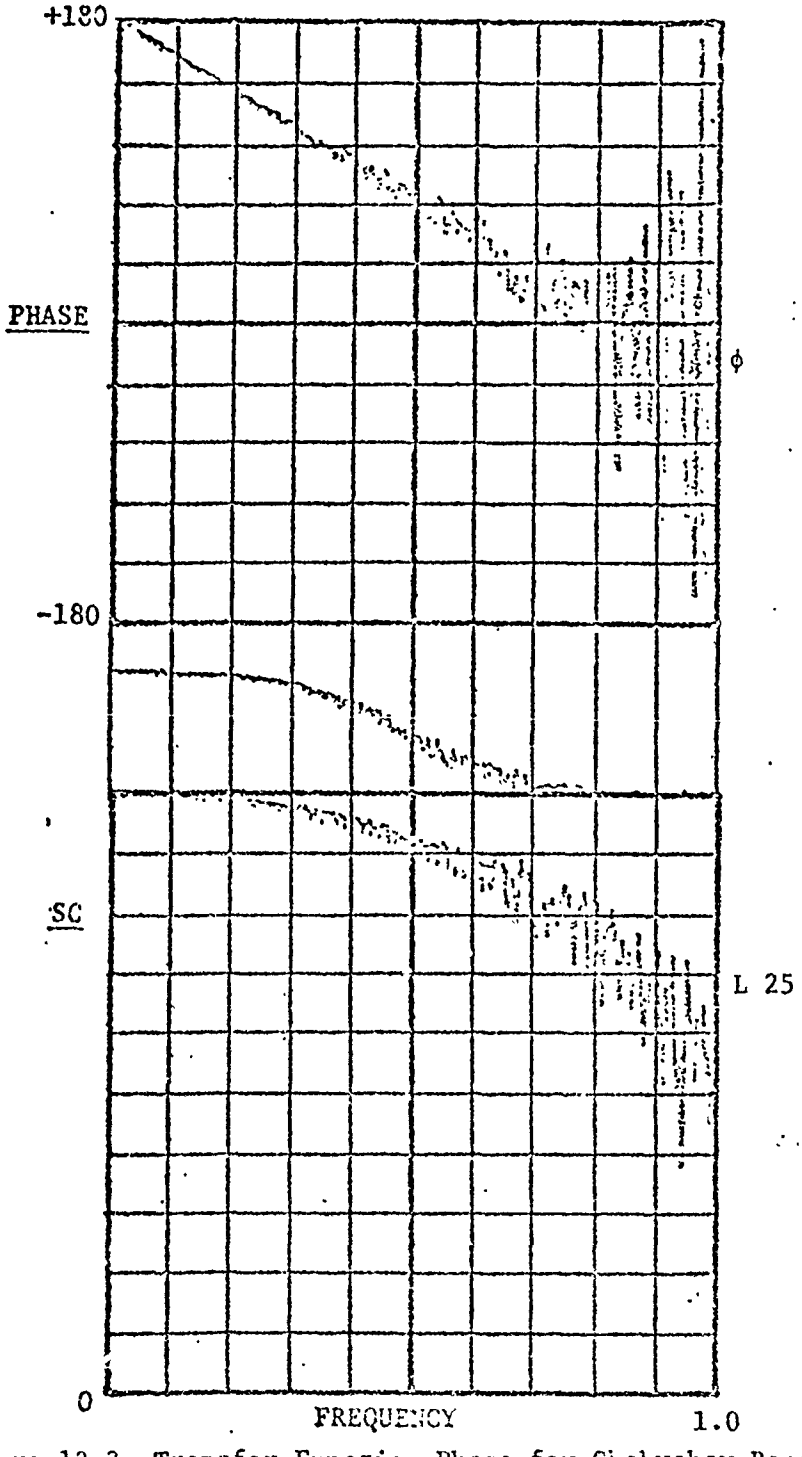

Figure 13-3 Transfer Function Phase for Chebyshev Bandpass.

Perhaps the most interesting of the IIR filters tested was a 0.015-0.045 Hz notch filter. Figure 13-4 shows the notch found in the overnight test. The notch did not appear in the short test in Figure 13-5.

The results shown in Figures 13-6 and 13-7 are remarkable. This was a long overnight test of the same 0.015 - 0.045 Hz IIR notch filter. The linear phase lead was the result of the Biomation anti-aliasing filter being used in a passive mode (bf). The lead is real. What is perhaps even more remarkable, although the data is not presented here, is that when the input and output filters were reversed, the result was a flat transfer function with a slight amount of lag, but not nearly so much lead as is shown in Figure 13-6. This shows that digital and passive analog filters may be used together to achieve remarkable (linear phase lead!) results. It also shows the nonlinear effects of using the two types of filters together. They obviously do not commute.

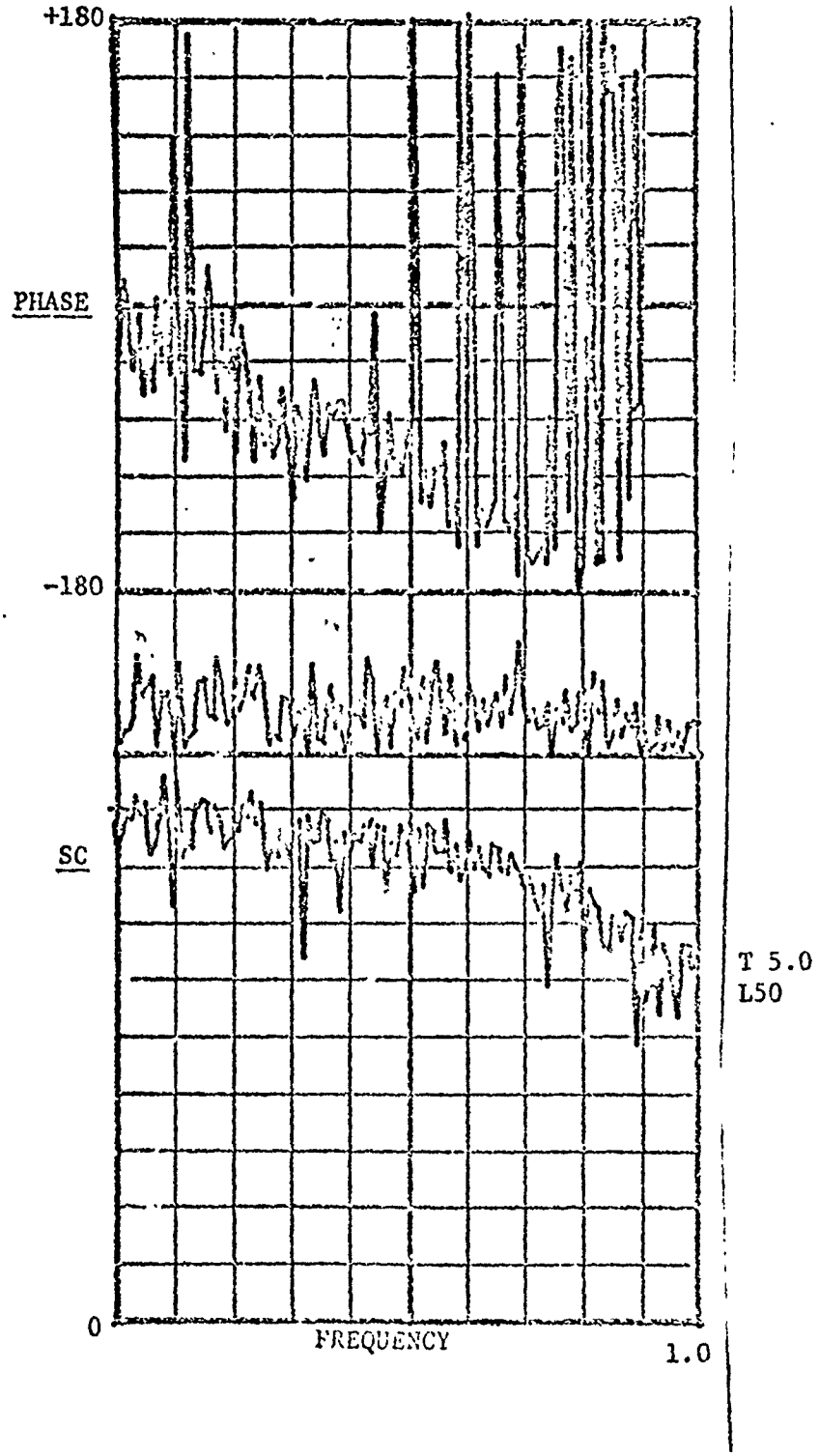

Figure 13-4. Overnight Test of
0.015 Hz to 0.045 Hz notch filter.

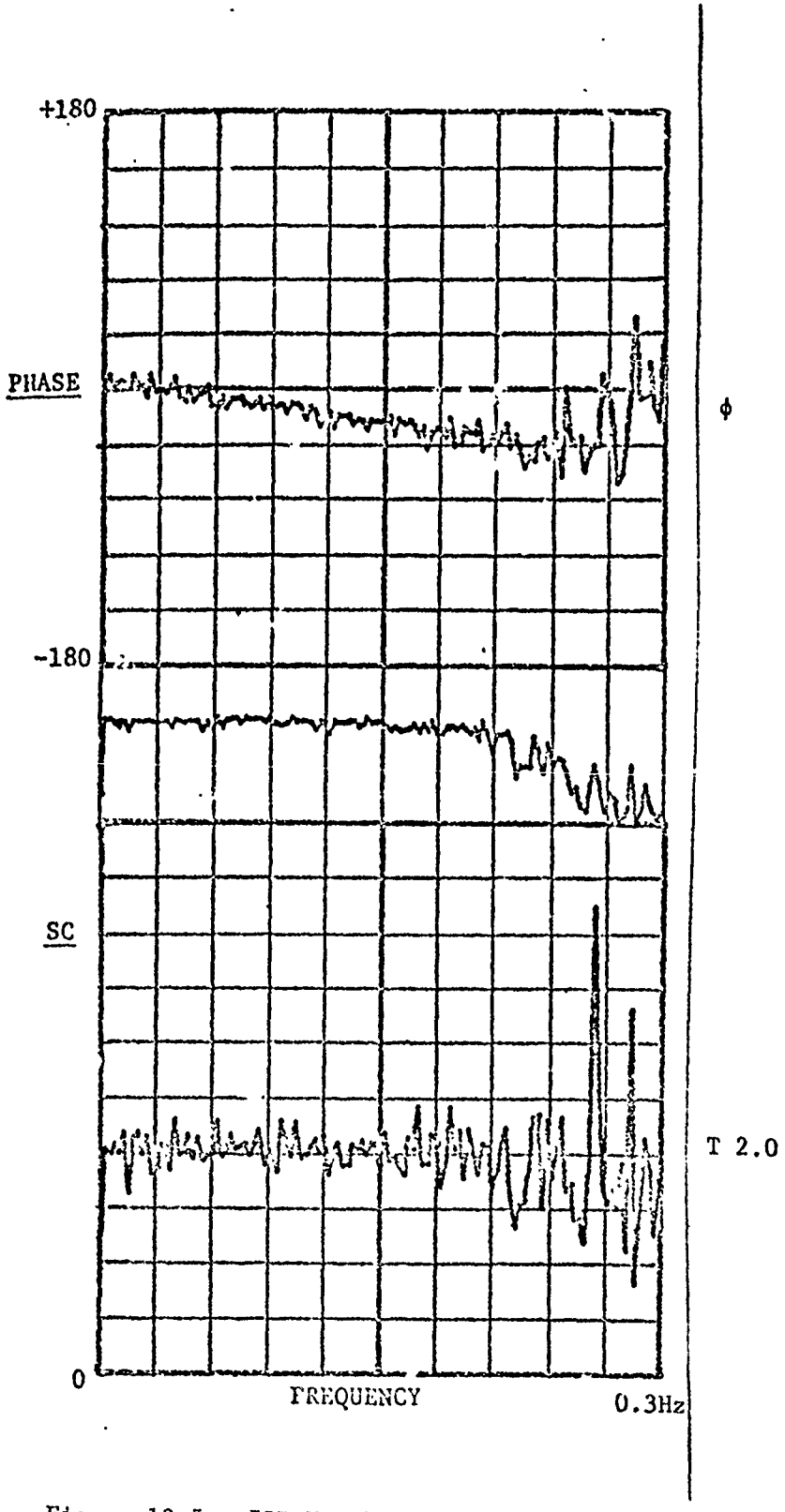

Figure 13-5. IIR Notch Filter, 0.015- 0.045 Hz, Short (40 min.) run.

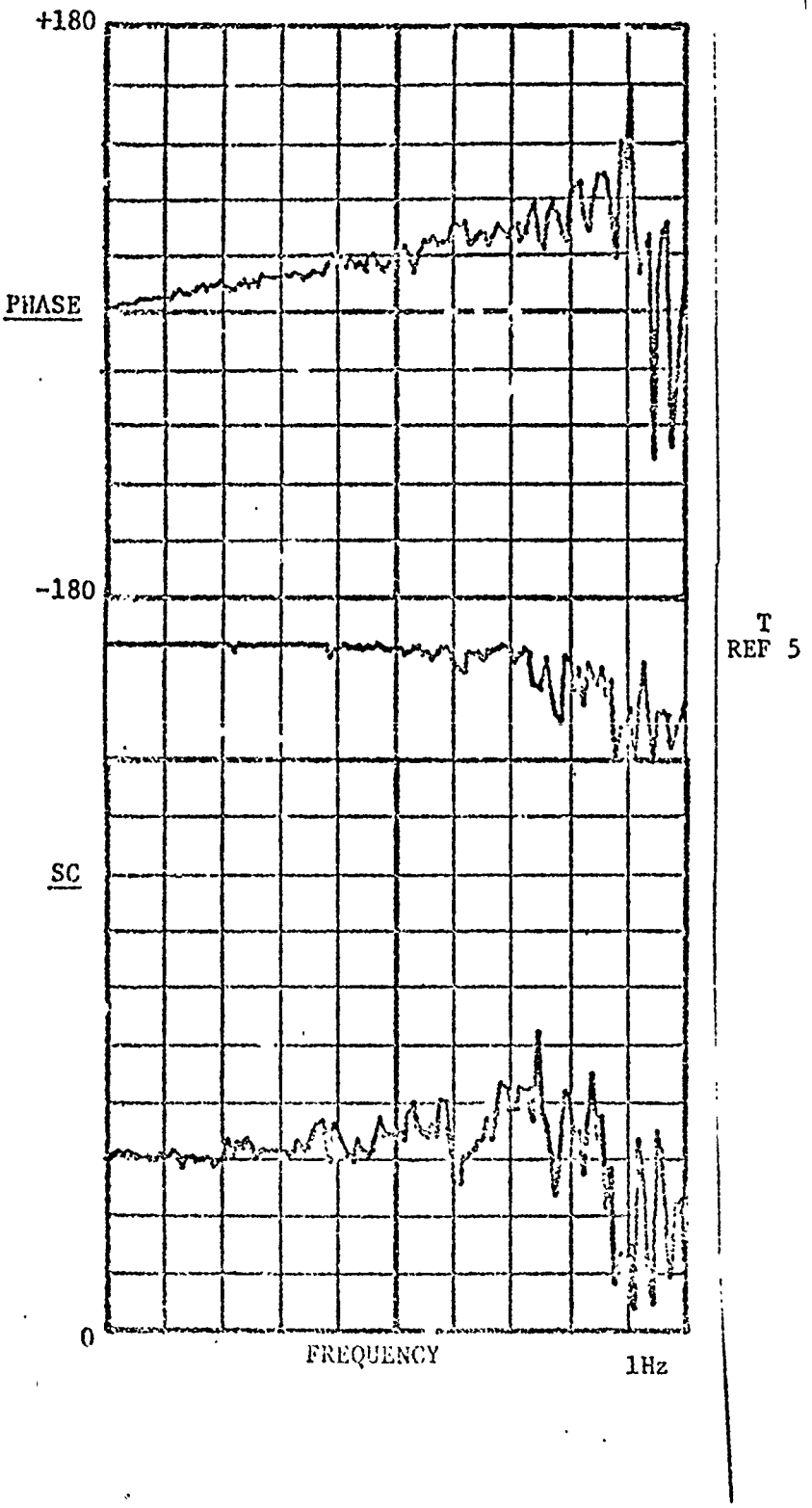

Figure 13-6. This remarkable linear phase lead was the result of the two-channel Biomation filter being used as a passive analog filter. The filter was the same IIR notch filter shown in Figures 13-4 and 13-5.

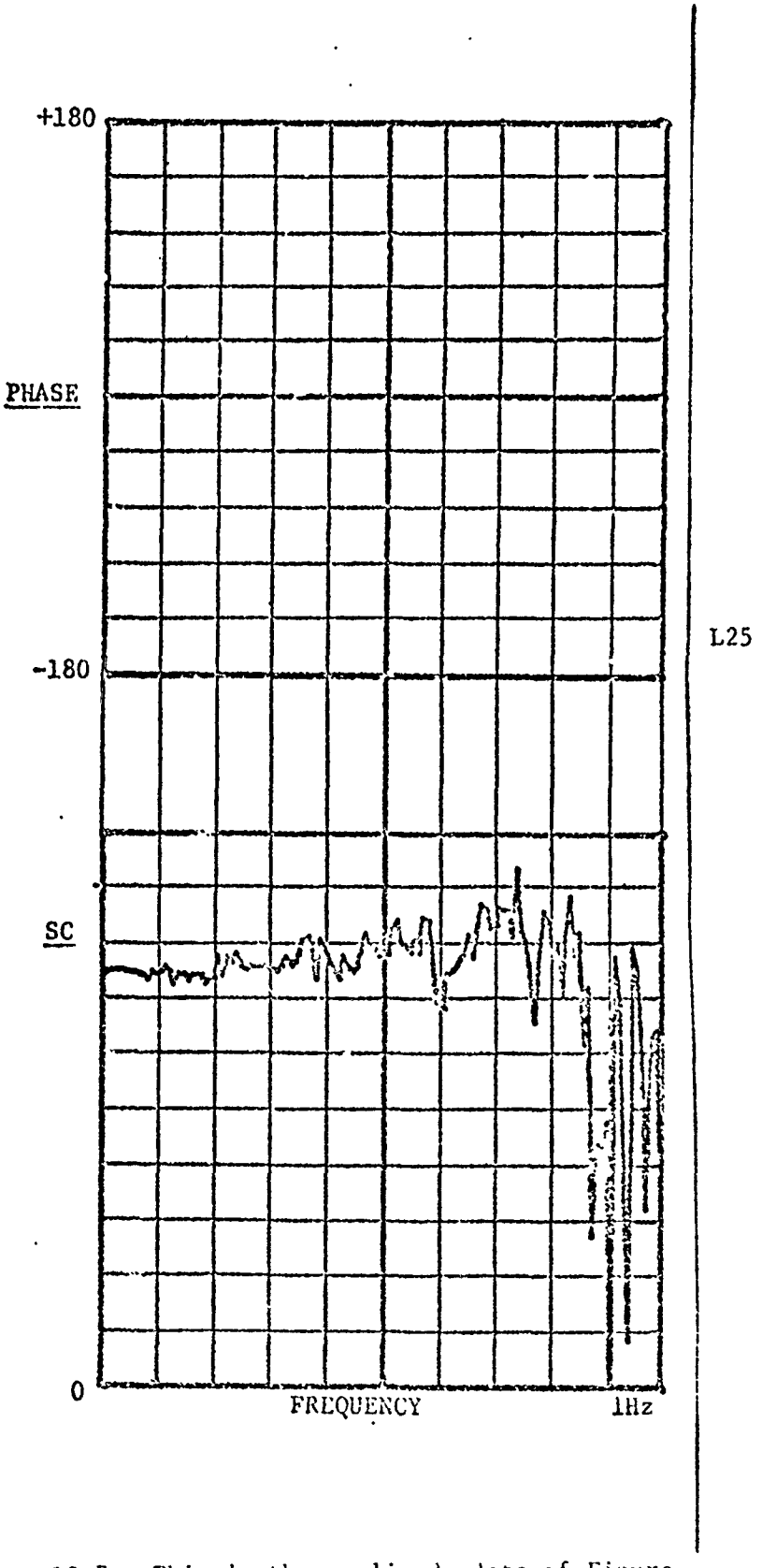

Figure 13-7. This is the amplitude data of Figure 13-6 shown in log form.

Optical slip rings are totally compatible with the modern laboratory trends toward digitizing the data as close to the source as possible and using automated mini-computer data acquisition systems.

The microprocessor based digital filter work for isopad seismic vibration control is summarized in this report.

SECTION 14

SUMMARY OF ISOPAD DIGITAL FILTER WORK FOR ISOPAD CONTROL

Using the four techniques as summarized below we were able to identify various types of digital filters which show significant promise for isopad control. These four techniques were:

1. Recursive digital filters analogous to common analog filters.
2. Variable time delay filters.
3. Finite Impulse Response Filters.
4. Infinite impulse response filters.

Of these four approaches the last was by far the most successful. These were the filters designed using the MAC/FIL digital filter design software package from Agbabian Associates. It is perhaps somewhat ironic because infinite impulse response filters have a reputation for having wildly fluctuating and quite unpredictable phase transfer funcitons. I say reputation because very little information is available either from the literature or from those familiar with digital filters. It was found, though, that these digital filters had nice ramps of phase lead which would be ideal for isopad control.

Reviewing the results of the other types of filters, the recursive digital filters yielded results which were very similar as expected to the analog filters of the same difference equations. Also as expected, they producted the predictable lag of the same magnitude as the corresponding analog filters. This was predicted and served to verify the digital filter execution programs, which was the intended result of these programs. These filters also yielded valuable information relative to the highest speed that we could expect a digital filter to be executed in real time using the pdp11/45 computer.

The "raw" digital filter execution program, which actually consists of the FORTRAN execution program configured to put out exactly the same value to the Datel 256 as it reads from the LPS 11 in the fastest manner possible with no arithmetic manipulations or filtering, the IDAC.MAC, the assembly language Datel 256 driver, would run at about a 113 Hz sample rate. With a very simple digital filter, such as a simple recursive digital filter which only simulates a simple one-stage passive RC filter, the program runs at about 100 Hz. This speed is really not adequate for many applications for the isopad controller.

In particular, since the frequency range of most interest for isopad control is the range from 1 Hz to 20 Hz, this makes a very difficult situation, especially when lead is required. Suppose at 20 Hz we have a minimum time delay between sample in and control signal out of 10 milliseconds. This is an almost insurmountable handicap when lead is desired. For this reason we were limited to test the filters usually at a maximum sample rate of 1 Hz. This was done with the idea that, while the filter execution program could not be made more efficient in the way the FORTRAN code was compiled to object code by the optimized compiler by writing an assembly language program, perhaps the sampling could be scheduled in such a way that required much less software overhead. The sampling mode using the LPS software to schedule the samples was chosen because it offered most accurate sample spacing. Sample spacing uniformity is absolutely critical in digital filtering because any "jitter" can cause a very spurious frequency response. But, the LPS software uses a large amount of processor time relative to the time needed to execute the filter itself. The slowed sample rates were advantageous in that tests could be run without interfering with the multi-user aspects of the pdp11/45 system, but they made the filters more or less useless for real-time applications.

The variable time delay filters were also found to be of little value. The predicted lead turned out to be variable magnitudes of lag because the delay through the filter at reasonable control sampling frequencies was greater than the variable delay effect of the filter. These filters proved to be useful in producing all sorts of nonlinear sorts of lag filters of almost any rolloff and phase plot shape required, but were of little use for the real-time applications.

The finite impulse response (FIR) filters proved to be very stable, and the FIR filter coefficient synthesis program was successfully run on the pdp 11/45, which was never accomplished for reasons to be discussed with the IIR filter coefficient synthesis program. Suitable lead in real time was never realized with this class of filters. The phase response was smooth and linear as expected, but in real time the result was always lag.

The most surprizing result of the FIR filter test program is that, like the IIR filters, the FIR filters produced unexpected results when used in conjunction or series with analog filters. Even when an ordinary analog lowpass filter was used to smooth the stairstep output to the Datel 256 digital to analog converter channel with a one-pole filter, the phase was made more positive

than without the filter and the phase roll-off was far more gradual. This was true even when a 200 Hz analog filter was used, which was far above the active range of the filter. Even though lead was never achieved, this is one of the several examples of the combination of analog and digital filters where an unexpected results was obtained from the digital time series analysis.

The results of the infinite impulse response filters were perhaps the most impressive.

The results of testing the infinite response (IIR) filters generated from the MAC/FIL software package can be summarized very easily. The phase responses obtained in the simulated runs were much better than could have been hoped for, and the phase responses obtained in the real-time tests with the pdp11/45 control loop and the Time/Data fourier analyzer were very disappointing.

Even filters like a lowpass Butterworth filter, which would be naturally stable under all conditions showed lead. The lead was not only positive with respect to the 0^{o} line, but actually had a positive slope over nearly two decades of frequency. This of course gave us high hopes of building a real-time controller, but because of delays through the processor or some unknown effect, the phase was never realized in real-time.

Another very interesting IIR filter was the bandpass Chebychev. This filter would be useful in giving gain to a particular band remote from an isopad resonance frequency. It gives nearly linear phase lead over nearly two decades of frequency. Used in conjunction with analog filters, this filter gave much promise, but again, its benefits were never realized in real time.

One of the filters which was of considerable interest because of the work of Emil Broderson was the notch filter. Although the phase naturally exhibits a sharp transition near the notch frequency, the phase usually exhibits lead before the amplitude falls off. Then, by using a sharp lowpass filter in conjunction with the filter, the lead can be utilized in a servo in a very beneficial sense. This was true of the analog filter that Emil designed and built. From the MAC/FIL simulation it appeared that this might be the case for the digital filter as well. This was never realized in real time, except in one case in which the two channels of the Biomation anti-aliasing filter were used as passive filters in a special configuration described in the past chapter.

This result was unique and showed that it was possible to utilize analog and digital filters together to get more lead than you would expect from either of them, or even the sum of their leads, taken individually. In particular, even when a digital filter with lead was used with a low pass analog filter with lag, the lead of the digital filter could be enhanced if the cutoff frequency of the analog filter was sufficiently above the Nyquist folding frequency of the digital filter. While we never found an analytical explanation for this, it was found to be very repeatable using the Time/Data fourier analyzer.

One of the frightening things that worried us at the onset of this project was that experts warned us that in order to get lead from a digital filter, we would probably have to use an infinite impulse response filter and that the phase transfer function of this class of filters would probably have too many wild fluctuations to be of any value whatsoever in a closed loop servo application and could probably be used to advantage in a post-processor configuration. This proved to be only half true. The infinite impulse response filters did indeed prove to be the only class of filters we implemented that showed promising phase characteristics. However, it is clearly not true that their phase transfer function plots show any wild fluctuations that would make them unsuitable for closed-loop servo applications

SECTION 15

THE MOST SIGNIFICANT TECHNICAL CONTRIBUTIONS

The major accomplishments of this work period can be briefly summarized as follows:

1. The invention, design, development, construction of a prototype, and testing of an electronic fiber optics communication system for bipolar analog signals of data acquisition quality.
2. The invention, development, design, construction of a prototype assembly, testing, and evaluation of a fiber optic slip ring.
3. The application of linear phase design techniques and finite impluse response (FIR) discrete-time or digital filters to the isopad stabilization problem.

The analog fiber optics communication system has several unique features. Among these are very low parts count and compactness, and more importantly, a novel encoding scheme. The encoding scheme utilizes a combination of pulse-width-modulation (PWM) and voltage-to-frequency-to-voltage (V/F/V) conversion to double the information transmittable through a fiber optic communication of a specified pulse repetition rate. This is especially important in the case of laser diodes since the pulse repetition rate is limited in most cases to frequencies less than the maximum repetition rates of commerically available voltage to frequency converters in integrated circuit form.

The high resolution fiber optics communications system (FOCS) uses the above techniques to reconstruct a ± 10 volt analog output signal from an identical ± 10 volt analog input signal.

Data collected on a very general V/F/V system is presented to give the designer information on V/F/V system dynamics at frequencies much higher than those considered to be in the V/F/V's system's useful range for data acquisition and communication purposes. This data shows that the V/F/V process may be useful for servo loop applications at much higher frequencies than it is for data acquisition and data communication applications.

The data on this system has proved to be of much interest and we have had a number of requests for information from both military and civilian organiza-

tions on how to determine the effective data rates on voltage-to-frequency-to-voltage systems and how to compare the informational content of the pulses to those of a digital analog-to-digital conversion and transmission system. The loop dynamics of this system are obviously complex and nearly impossible to analyze using a purely mathematical approach. This is why our results have proven to be so valuable. We apparently have the only actual data since we are apparently the only group which has had access to a Fourier analyzer while testing avoltage-to-frequency-to-voltage system. By using the digital time series analysis techniques of this device (primarily correlation, coherence, and transfer function analysis) we have some unique data on the performance of this very popular class of devices.

Our work on optical slip rings has been very well received, partially because of the success of our prototype optical slip ring assembly and particularly because of the well known shortcomings of mechanical slip rings or commutators as they are sometimes called. The mechanical slip rings commonly used to collect data from rotating test fixtures suffer from such problems as friction, backlash, continuity failures, wear-limited lifetime, noise, the need for precious metals, and expensive and time-consuming preventive maintenance. This report discusses a multi-channel fiber optic slip ring assembly which avoids these problems. The assembly is interfaced with digital systems and a custom designed analog-in, analog-out high resolution fiber optics data communication system to provide the control and data acquisition functions during automated tests of inertial guidance components. We also did research and reported on design tradeoffs between multiplexing and providing additional optical channels for milti-channel operation and explored these alternatives relative to currently available electronic, electro-optic, and optical components.

The research and development effort on the mechanical slip rings shows that optical slip rings are a practical alternative to mechanical slip rings and offer cost and performance advantages for signal transmission using standard componets. Mechanical and electrical isolation are among the advantages to be gained. Mechanical and optical slip rings can complement one another if mechanical slip rings are used for power transmission and optical slip rings are used for signal transmission.

SECTION 16

SUMMARY OF THE PUBLICATIONS

Three publications have resulted from our research in collaboration with FJSRL personnel in the areas of analog fiber optics data communications and the fiber optic slip rings. Two of them have been published and the third is now pending publication. The two that have been published have generated enthusiastic responses from both civilian and military agencies.

The references to these publicaions are as follows:

1. Grimes, G. J. and Stevens, D. R. "A High Resolution Analog Fiber Optics Data Communications System," Proceedings of the SPIE, Vol. 95, Modern Utilization of Infrared Technology II, 1976.

2. Grimes, G. J., Monaco, S. J., and Stevens, D. R. "Fiber Optic Slip Rings for Totating Test Fixture Data Acquisition," Proceedings of the 23rd International Instrumentation Symposium, Instrumentation in in the Aerospace Industry, Proceedings of the ISA (Instrument Society of America), Vol. 23, 1977.

3. Grimes, G. J. and Stevens, D. R. "A High Resolution Analog Fiber Optics Data Communications System," to be published (accepted for publication) in Optical Engineering, the technical journal of the Society of Photo-Optical Instrumentation Engineers (SPIE).

SECTION 17

SUMMARY OF THE PATENT PROCEEDINGS ON THE FIBER OPTIC SLIP RINGS

Kappa Systems, Inc., is currently working with a law firm to file a patent on the fiber optic slip ring developed under this contract.

The search has been completed and there are no similar devices patented. Also, the law firm has verified that the device is patentable. We are currently working with Mr. Gene W. Stockman and Mr. Scott F. Partridge at the following law firm:

Schuyler, Birch, Swindler, McKie and Beckett
One Thousand Connecticut Avenue
Washington, D.C. 20036
(202) 296-5500

APPENDIX A

SUMMARY OF SOFTWARE

Two major types of programs were used in this effort: the filter coefficient synthesis programs and the real-time filter execution programs. The filter coefficient synthesis programs are large FORTRAN programs which calculate filter coefficients for a filter given parameters such as the corner frequencies and the weights for each band. The digital filter execution programs are small FORTRAN programs which call an assembly language driver to handle the D/A output.

The filter coefficient synthesis programs used were of two types. These were:

1. A Finite Impulse Response (FIR) filter synthesis program.
2. An infinite impulse response (IIR) filter synthesis program.

The FIR synthesis program was taken from Theory and Applications of Digital Signal Processing by Lawrence R. Rabiner, Prentice Hall, 1975. This program was adjusted to run in an interactive mode in the 11/45. A listing of this program is shown in Appendix D.

The IIR program used was one from the MAC/FIL software package. This package was purchased in 1974 for DFEE (Dean of Faculty: Department of Electrical Engineering) with about $5000 of FJSRL funds. This package consists of three programs:

1. MAC/FIL: generates coefficients for lowpass, highpass, bandpass, and band-reject filters of many kinds, including Butterworth. Chebychev types I and II, and elliptic..

2. MAC/APX: generates filter parameters from specified gain functions input to it. Thus, it can be employed to generate matched filters, Weiner-Hopf filters, or any type of filter defined by its amplitude which cannot be generated by MAC/FIL.

3. MAC/SIM: simulates digital filters implemented in fixed point arithmetic. Through its use many hardware design problems can be answered without having to build special purpose devices.

The IIR filters reported on here were generated through the use of MAC/FIL. This program required numerous modifications to run properly. Most of these modifications were performed by Airman Gary Lear of FJSRL and Capt. Perry Cole of the computer center.

The MAC/APX program was never successfully run. Extensive modifications will probably be required to run this program.

The MAC/SIM program was not needed since we could easily test the filter response with the time/data fast fourier analyzer.

The MAC/FIL program was used exclusively on the Burroughs 6700 at the Computer Center.

The MAC/FIL, MAC/APX, and MAC/SIM programs are not reproduced in the appendices since the copyright of the software might be violated by this procedure.

The digital filter execution programs are very similar except for the actual filtering part which calculates the output from the appropriate sum of the products. The filter execution programs are all self contained except for the I/O drivers and handlers. Although it would have been more convenient to make the filter execution program be the same in all cases and merely call a subroutine to execute a specific filter, the nonmodular approach was taken to improve filter performance. The subroutine call was found to just add software overhead and increase the time delay through the filter.

The filter execution program called INOUT, FTN simply puts the input value to the DAC of the Datel 256 system with the absolute minimum time delay of the filter. The filter acts as a simple passive lowpass filter for frequencies of a sizeable fraction of the sample frequency. The program GOOD.FTN is a minor modification of INOUT.FTN to run the digital equivalent of simple one-stage passive RC filter in an interactive mode.

The programs which execute the variable time delay filters are very similar. An example is shown in Appendix E.

The programs which execute the FIR filters include the examples BAD.FTN, BAND.FTN, NINE9.FTN, and DIFF32.FTN shown in Appendix F.

The IIR filter execution programs include the programs CASE8.FTN, CASE8F.FTN, HONEYF.FTN, and BUTTER.FTN shown in Appendix G.

The assembly language driven IDAC.MAC is shown in Appendix H.

A list of all the programs included in the following appendices follows:

1.	INOUT.FTN	Program to test response of system with no filter.
2.	GOOD.FTN	One-stage passive RC filter (interactive).
3.	ASKFIR.FTN	FIR coefficient synthesis program from Raginer and Gold. Modified to run in an interactive mode on pdp 11/45.
4.	BAD.FTN	Linear phase FIR program, N = 9.
5.	NINE9.FTN	Linear phase FIR filter execution program, N = 9.
6.	DIFF32.FTN	Linear phase FIR differentiator, V = 32. Symmetrical filter.
7.	BAND.FTN	Fast execution bandpass linear phase FIR filter execution program, N = 32, (for N even, coefficients).
8.	DELAY13.FTN	Variable time delay filter. Unity gains for all frequencies. Time delay is pregressively less for higher frequencies. Interactive.
9.	CASE8.FTN	IIR filter execution program for 8 recursive and 9 non-recursive coefficients. N = 8. 0.015 Hz to 0.045 Hz bandpass. H's are nonsymmetrical; G's are symmetrical.
10.	CASE8F.FTN	IIR execution program for N = 8.
11.	HONEYF.FTN	IIR filter execution program N = 5, nonsymmetrical coefficients.
12.	BUTTER.FTN	IIR filter execution program with coefficients for lowpass Butterworth filter. N = 5. One nonrecursive and four recursive weights.
13.	IDAC.MAC	The assembly driver for the Datel 256 system.
14.	NOTCH.FTN	IIR execution program with 6 recursive and 7 nonrecursive weights.
15.	DATEL.FTN	Program written by Capt. Lind to exercise the Datel 256 system by writing a digital triangle wave to it.

APPENDIX B

Program Listing: INOUT.FTN

This program tests the system response with no filtering done.

```
FORTRAN IV-PLUS V02-51          11:13:01    28-APR-78          PAGE 1
:OUT.FTH       /TR:BLOCKS/WR

0001           DIMENSION IBUF(6),IRATE(2),ISB(2)
0002           COMMON IRATE,IDATA,Y,FREQ
               C
0003           WRITE (5,80)
0004      80   FORMAT('$ ENTER LOW PASS CUTOFF FREQUENCY IN HERTZ   ')
0005           READ (5,81) FREQ
0006      81   FORMAT(F4.2)
               C
               C     READ IN SAMPLE PERIOD IN MILLISECONDS
0007           WRITE (5,30)
0008      30   FORMAT('$ENTER SAMPLE PERIOD IN MILLISECONDS')
0009           READ (5,31)IRATE(2)
0010      31   FORMAT (I6)
               C     INITIALIZE FILTER FOR SUBROUTINE CUTOFF
0011           Y=0.0
               C
               C     INITIALIZE LABORATORY PERIPHERAL SYSTEM
0012           CALL ASLSLN (1,ISB)
               C
               C     DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0013           ICHAN=0
               C
               C     DESIGNATE REGISTER FOR LPS11 FLAG SET
0014           IEFN=7
               C
               C     SPECIFY TIME BETWEEN SAMPLES IN MILLISECONDS
               C     IRATE(2)=50
               C
               C     PUT LPS11 RTS ROUTINE IN MILLISECOND SAMPLING MODE
0015           IRATE(1)=2
               C
               C     INITIATE SYNCHRONOUS SAMPLING
0016      90   CALL RTS(IBUF,6,0,IRATE,IEFN,0.1,ISB)
               C
0017           INDX=5
0018      10   CALL WAITFR(IEFN)
0019      15   CALL CLREF(IEFN)
0020           SIGMA=IBUF(INDX)
               C
               C     SCALE IN VOLTS
0021           IDATA=10000.*(SIGMA/2048.)-10000.
               C
               C     CALL FILTER ROUTINE
0022           CALL CUTOFF
               C
               C     CALL LPS11 LED DISPLAY ROUTINE
0023           CALL LED(IDATA)
               C
```

```
 FORTRAN IV-PLUS V02-51          11:13:01    28-APR-78          PAGE 2
)NOUT.FTN       /TR:BLOCKS/WR

        C     CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0024            CALL IDAC(IDATA,ICHAN)
        C
        C     ADJUST POINTERS FOR LPS11
        C     AND CLEAR HALF BUFFER FOR NEXT SAMPLE
0025            CALL  ADJLPS(IBUF,1)
        C
0026            INDX=INDX+1
        C
        C     CHECK STATUS REGISTER FOR PROPER I/O
        C     AND TERMINATE IF STATUS NOT CORRECT
0027            IF (INDX.GT.6) INDX=5
0028            IF (ISB(2).GE.1) GO TO 15
0029            IF (ISB(1).NE.0) GO TO 95
0030            GO TO 10
0031    95      CONTINUE
        C
        C     IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0032            WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0033    200     FORMAT(4I12)
0034            END


PROGRAM SECTIONS

 NAME        SIZE                  ATTRIBUTES

$CODE1  000524   170            RW,I,CON,LCL
$PDATA  000020     8            RW,D,CON,LCL
$IDATA  000222    73            RW,D,CON,LCL
$VARS   000032    13            RW,D,CON,LCL
.$$$$.  000016     7            RW,D,OVR,GBL


TOTAL SPACE ALLOCATED = 001036   271

.INOUT=INOUT
```

APPENDIX C

Program Listing: GOOD.FTN

This is a simple digital filter which is the digital analogue of a simple one-stage passive RC filter which runs on the pdp 11/45 in an interactive mode.

```
FORTRAN IV-PLUS V02-51          11:10:38    28-APR-78          PAGE 1
GOOD.FTN        /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2),ISB(2)
        C
        C       THIS PROGRAM SYNTHESIZES AND EXECUTES
        C       A FIRST ORDER RECURSIVE FILTER CORRESPONDING
        C       TO A ONE-STAGE PASSIVE RC FILTER
        C
        C       THE ALGORITHM ON WHICH THIS FILTER IS BASED
        C       IS VALID ONLY WHEN THE TIME CONSTANT IS MUCH
        C       GREATER THAN THE PERIOD BETWEEN SAMPLES.
        C       THE TIME CONSTANT SHOULD BE AT LEAST THREE
        C       TIMES AS LARGE AS THE SAMPLE PERIOD
        C
        C
0002            WRITE(5,80)
0003         80 FORMAT('$ ENTER LOW PASS CUTOFF FREQUENCY IN HERTZ-FLT.PT.  ')
0004            READ (5,81) FREQ
0005         81 FORMAT(F4.2)
        C
        C       READ IN SAMPLE PERIOD IN MILLISECONDS
0006            WRITE (5,30)
0007         30 FORMAT('$ ENTER SAMPLE PERIOD IN MILLISECONDS-INTEGER   ')
0008            READ (5,31) IRATE(2)
0009         31 FORMAT (I6)
        C
        C       INITIALIZE FILTER
        C
        C
0010            Y=0.0
        C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0011            CALL ASLSLN (1,ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0012            ICHAN=0
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0013            IEFN=7
        C
        C
        C       PUT LPS11 RTS ROUTINE IN MILLISECOND SAMPLING MODE
0014            IRATE(1)=2
        C
        C       CALCULATE RC TIME CONSTANT IN SECONDS
0015            RC=1./(FREQ*6.28)
        C
        C
        C       CALCULATE SAMPLE INTERVAL IN SECONDS
0016            ST=FLOAT(IRATE(2))/1000.
        C
```

```
FORTRAN IV-PLUS V02-51          11:10:38    20-APR-78          PAGE 2
GOOD.FTN        /TR:BLOCKS/WR

        C     CALCULATE FILTER PARAMETER
0017            TCON=ST/RC
0018            TCONC=1.-TCON
        C
        C
        C     TEST TO SEE IF FILTER WILL BE STABLE:
        C     IF UNSTABLE PROGRAM WILL TERMINATE AND PRINT 'UNSTABLE-
        C     SAMPLE RATE TOO LOW FOR TIME CONSTANT'
        C
0019            IF (TCON.GE.1) GO TO 301
0020            GO TO 555
0021      301 WRITE(5,201)
0022      201 FORMAT(' UNSTABLE-SAMPLE RATE TOO SLOW FOR TIME CONSTANT')
0023            GO TO 195
0024      555 CONTINUE
        C
        C
        C     INITIATE SYNCHRONOUS SAMPLING
0025    90    CALL PTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
        C
0026            INDX=5
0027    10    CALL WAITFR(IEFN)
0028    15    CALL CLREF(IEFN)
0029            SIGMA=IBUF(INDX)
        C
        C     SCALE IN VOLTS
0030            IDATA=10000.*(SIGMA/2048.)-10000.
        C
        C     BEGIN FILTER ROUTINE
        C
0031            Y=TCONC*Y+TCON*IDATA
0032            IDATA=Y
        C     CALL LPS11 LED DISPLAY ROUTINE
0033            CALL LED(IDATA)
        C
        C     CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0034            CALL IDAC(ICHAN,IDATA)
        C
        C     ADJUST POINTERS FOR LPS11
        C     AND CLEAR HALF BUFFER FOR NEXT SAMPLE
0035            CALL  ADJLPS(IBUF,1)
        C
0036            INDX=INDX+1
        C
        C     CHECK STATUS REGISTER FOR PROPER I/O
        C     AND TERMINATE IF STATUS NOT CORRECT
0037            IF (INDX.GT.6) INDX=5
0038            IF (ISB(2).GE.1) GO TO 10
```

```
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JOD.FTN        /TR:BLOCKS/WR

0039          IF (ISB(1).NE.0) GO TO 95
0040          GO TO 10
0041     95   CONTINUE
         C
         C    IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0042          WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0043     200  FORMAT(4I12)
0044     195  CONTINUE
0045          END


*PROGRAM SECTIONS

.NAME       SIZE                ATTRIBUTES

$CODE1   000676   223            RW,I,CON,LCL
$IDATA   000024    10            RW,D,CON,LCL
$LDATA   000330   108            RW,D,CON,LCL
$ARS     000070    28            RW,D,CON,LCL


*OTAL SPACE ALLOCATED = 001342   369

. JOD=GOOD
```

APPENDIX D

Program Listing: ASKFIR.FTN

This is the FIR coefficient synthesis program from Rabiner and Gold as modified to run in an interactive manner on the pdp 11/45.

```
      COMMON PI2,AD,DEV,X,Y,GRID,DES,WT,ALPHA,IEXT,NFCNS,NGRID

      DIMENSION IEXT(66),AD(66),X(66),Y(66),ALPHA(66)
      DIMENSION H(66)
      DIMENSION DES(1045),GRID(1045),WT(1045)
      DIMENSION EDGE(20),FX(10),WTX(10),DEVIAT(10)
      DOUBLE PRECISION PI2,P1
      DOUBLE PRECISION AD,DEV,X,Y
      PI2=6.28318530717958
      P1=3.14159265358979
C     THIS PROGRAM IS SET UP FOR A MAXIMUM LENGTH OF 128, BUT
C     THIS UPPER LIMIT CAN BE CHANGED BY REDIMENSIONING THE
C     ARRAYS IEXT, AD,ALPHA, X,Y, H TO BE NFMAX/2+2.
C     THE ARRAYS DES, GRID, AND WT MUST DIMENSIONED
C     16 (NFMAX/2+2)
C
      NFMAX=128
  100 CONTINUE
      JTYPE=0
C
C      PROGRAM INPUT SECTION
      WRITE(5,4398)
 4398 FORMAT('  ENTER FILTER LENGTH;TYPE OF FILTER:1=MULTIPLE')
      WRITE(5,4397)
 4397 FORMAT(' PASSBAND/STOPBAND,2=DIFFERENTIATOR,3=HILBERT')
      WRITE(5,4396)
 4396 FORMAT(' TRANSFORM FILTER:NUMBER OF BANDS, AND GRID DENSITY')
C
      READ (5,4444) NFILT,JTYPE,NBANDS,LGRID
 4444 FORMAT(4I4)
C     IF(NFILT.GT.NFMAX.OR.NFILT.LT.3) CALL ERROR
      IF(NBANDS.LE.0) NBANDS=1
C
C     GRID DENSITY IS ASSUMED TO BE 16 UNLESS SPECIFIED
C     OTHERWISE
C
      IF(LGRID.LE.0) LGRID=16
      JB=2*NBANDS
      WRITE(5,4388)
 4388 FORMAT(' ENTER BANDEDGES(FLOATING POINT) ')
      READ (5,3333) (EDGE(J),J=1,JB)
      WRITE(5,4387)
 4387 FORMAT(' ENTER DESIRED FUNCTION FOR EACH BAND ')
      READ (5,3333) (FX(J),J=1,NBANDS)
      WRITE(5,4386)
 4386 FORMAT(' ENTER WEIGHT FUNCTION IN EACH BAND ')
      READ (5,3333) (WTX(J),J=1,NBANDS)
 3333 FORMAT(20F10.2)
      WRITE(5,4444) NFILT,JTYPE,NBANDS,LGRID
      WRITE(5,3333) (EDGE(J),J=1,JB)
      WRITE(5,3333) (FX(J),J=1,NBANDS)
      WRITE(5,3333) (WTX(J),J=1,NBANDS)
      IF(JTYPE.EQ.0) CALL EPROR
```

Program ASKFIR

```
      NEG=1
      IF(JTYPE.EQ.1) NEG=0
      NODD=NFILT/2
      NODD=NFILT-2*NODD
      NFCNS=NFILT/2
      IF(NODD.EQ.1.AND.NEG.EQ.0) NFCNS=NFCNS+1
C
C     SET UP THE DENSE GRID.  THE NUMBER OF POINTS IN THE GRID
C     IS (FILTER LENGTH +   1)*GRID DENSITY/2
C
      GRID(1)=EDGE(1)
      DELF=LGRID*NFCNS
      DELF=0.5/DELF
      IF (NEG.EQ.0) GO TO 135
      IF (EDGE(1).LT.DELF) GRID(1)=DELF
  135 CONTINUE
      J=1
      L=1
      LBAND=1
  140 FUP=EDGE(L+1)
  145 TEMP=GRID(J)
C
C     CALCULATE THE DESIRED MAGNITUDE RESPONSE AND THE WEIGHT
C     FUNCTION OF THE GRID
C
      DES(J)=EFF(TEMP,FX,WTX,LBAND,JTYPE)
      WT(J)=WATE(TEMP,FX,WTX,LBAND,JTYPE)
      J=J+1
      GRID(J)=TEMP+DELF
      IF(GRID(J).GT.FUP) GO TO 150
      GO TO 145
  150 GRID(J-1)=FUP
      DES(J-1)=EFF(FUP,FX,WTX,LBAND,JTYPE)
      WT(J-1)=WATE(FUP,FX,WTX,LBAND,JTYPE)
      LBAND=LBAND+1
      L=L+2
      WRITE(5,1000)
      WRITE(5,2765)
 2765 FORMAT(' HERE WE GO AGAIN')
      IF(LBAND.GT.NBANDS) GO TO 160
      GRID(J)=EDGE(L)
      GO TO 140
  160 NGRID=J-1
      IF(NEG.NE.NODD) GO TO 165
      IF (GRID(NGRID).GT.(0.5-DELF)) NGRID=NGRID-1
  165 CONTINUE
C
C     SET UP A NEW APPROXIMATION PROBLEM WHICH IS EQUIVALENT
C     TO THE ORIGINAL PROBLEM
C
      IF(NEG) 170,170,180
  170 IF (NODD.EQ.1) GO TO 200
      DO 175 J=1,NGRID
      CHANGE=DCOS(PI*GRID(J))
```

Program ASKFIR

```
      DES(J)=DES(J)/CHANGE
  175 WT(J)=WT(J)*CHANGE
      GO TO 200
  180 IF (NODD.EQ.1) GO TO 190
      DO 185 J=1,NGRID
      CHANGE=DSIN(PI*GRID(J))
      DES(J)=DES(J)/CHANGE
      GO TO 200
  185 WT(J)=WT(J)*CHANGE
  190 DO 195 J=1,NGRID
      CHANGE=DSIN(PI2*GRID(J))
      DES(J)=DES(J)/CHANGE
C
  195 WT(J)=WT(J)*CHANGE
C     INITIAL GUESS FOR THE EXTREMAL FREQUENCIES--EQUALLY
C     SPACED ALONG THE GRID
C
  200 TEMP=FLOAT(NGRID-1)/FLOAT(NFCNS)
      DO 210 J=1,NFCNS
  210 IEXT(J)=(J-1)*TEMP+1
      IEXT(NFCNS+1)=NGRID
      NM1=NFCNS-1
      NZ=NFCNS+1
C
C     CALL THE REMEZ EXCHANGE ALGORITHM TO DO THE APPROXIMATION
C     PROBLEM
C
      CALL REMEZ(EDGE,NBANDS)
 1000 FORMAT(' HERE WE GO')
      WRITE(5,1000)
C
C     CALCULATE THE IMPULSE RESPONSE
C

      IF(NEG) 300,300,320
  300 IF(NODD.EQ.0) GO TO 310
      DO 305 J=1,NM1
  305 H(J)=0.5*ALPHA(NZ-J)
      H(NFCNS)=ALPHA(1)
      GO TO 350
  310 H(1)=0.25*ALPHA(NFCNS)
      DO 315 J=2,NM1
  315 H(J)=0.25*(ALPHA(NZ-J)+ALPHA(NFCNS+2-J))
      H(NFCNS)=0.5*ALPHA(1)+0.25*ALPHA(2)
      GO TO 350
  320 IF(NODD.EQ.0) GO TO 330
      H(1)=0.25*ALPHA(NFCNS)
      H(2)= 0.25*ALPHA(NM1)
      DO 325 J=3,NM1
  325 H(J)=0.25*(ALPHA(NZ-J)-ALPHA(NFCNS+3-J))
      H(NFCNS)=0.5*ALPHA(1)-0.25*ALPHA(3)
      H(NZ)=0.0
      GO TO 350
  330 H(1)=0.25*ALPHA(NFCNS)
```

Program ASKFIR

```
      DO 335 J=2,NFII
  335 H(J-1)=0.25*(ALPHA(NZ-J)-ALPHA(NFCNS+2-J))
      H(NFILT)=0.5*ALPHA(1)-0.25*ALPHA(2)
      WRITE (6,5,1000)
C
C     PROGRAM OUTPUT SECTION
C
  350 WRITE (6,360)
  360 FORMAT(1H1, 70(1H*)//25X,' FINITE IMPULSE RESPONSE (FIR)'/
     125X,' LINEAR PHASE DIGITAL FILTER DESIGN'/
     225X,' REMEZ EXCHANGE ALGORITHM'/)
      IF(JTYPE.EQ.1) WRITE (6,365)
  365 FORMAT(25X,' BANDPASS FILTER'/)
      IF(JTYPE.EQ.2) WRITE (6,370)
  370 FORMAT(25X,' DIFFERENTIATOR'/)
      IF(JTYPE.EQ.3) WRITE (6,375)
  375 FORMAT(25X,' HILBERT TRANSFORMER')
      WRITE (6,378) NFILT
  378 FORMAT(15X,' FILTER LENGTH = ',I3/)
      WRITE (6,380)
  380 FORMAT(15X,' ***** IMPULSE RESPONSE *****')
      DO 381 J=1,NFCNS
      K=NFILT+1-J
      IF(NEG.EQ.0) WRITE (6,382) J,H(J),K
      IF(NEG.EQ.1) WRITE (6,383) J,H(J),K
  381 CONTINUE
  382 FORMAT(20X,' H(',I3,') = ',E15.8,' = H(',I4,')')
  383 FORMAT(20X,' H(',I3,') = ',E15.8,' = -H(',I4,')')
      IF(NEG.EQ.1.AND.NODD.EQ.1) WRITE (6,384) NZ
  384 FORMAT(20X,'H(',I3,') = 0.0')
      DO 450 K=1,NBANDS,4
      KUP=K+3
      IF(KUP.GT.NBANDS) KUP=NBANDS
      WRITE (6,385) (J,J=K,KUP)
  385 FORMAT(/24X,4(' BAND',I3,8X))
      WRITE (6,390) (EDGE(2*J-1),J=K,KUP)
  390 FORMAT(2X,' LOWER BAND EDGE',5F15.9)
      WRITE(6,395) (EDGE(2*J),J=K,KUP)
  395 FORMAT(2X,' UPPER BAND EDGE',5F15.9)
      IF(JTYPE.NE.2) WRITE (6,400) (FX(J),J=K,KUP)
  400 FORMAT(2X,' DESIRED VALUE' ,2X,5F15.9)
      IF(JTYPE.EQ.2) WRITE (6,405) (FX(J),J=K,KUP)
  405 FORMAT(2X,' DESIRED SLOPE',2X,5F15.9)
      WRITE (6,410) (WTX(J),J=K,KKUP)
  410 FORMAT(2X,' WEIGHTING',6X,5F15.9)
      DO 420 J=K,KUP
  420 DEVIAT(J)=DEV/WTX(J)
      WRITE(6,425) (DEVIAT(J),J=K,KUP)
  425 FORMAT(2X,' DEVIATION',6X,5F15.9)
      IF(JTYPE.NE.1) GO TO 450
      DO 430 J=K,KUP
  430 DEVIAT(J)=20.0*ALOG10(DEVIAT(J))
      WRITE (6,435) (DEVIAT(J),J=K,KUP)
  435 FORMAT(2X,' DEVIATION IN DB',5F15.9)
```

Program ASKFIR

```
  450 CONTINUE
      WRITE (6,455) (GRID(IEXT(J)),J=1,NZ)
  455 FORMAT(/2X,' EXTREMAL FREQUENCIES'/(2X,5F12.7))
      WRITE (6,460)
  460 FORMAT(/1X,70(1H*)/1H1)
C     IF(NFILT.NE.0) GO TO 100
      STOP
      END
C
      FUNCTION EFF(TEMP,FX,WTX,LBAND,JTYPE)
C
C     FUNCTION TO CALCULATE THE DESIRED MAGNITUDE RESPONSE
C     AS A FUNCTION OF FREQUENCY.
C
      DIMENSION FX(5),WTX(5)
      IF(JTYPE.EQ.2) GO TO 1
      EFF=FX(LBAND)
      RETURN
    1 EFF=FX(LBAND)*TEMP
      RETURN
      END
C
C
C
      FUNCTION WATE(TEMP,FX,WTX,LBAND,JTYPE)
C
C     FUNCTION TO CALCULATE THE WEIGHT FUNCTION AS A
C     FUNCTION OF FREQUENCY.
C
      DIMENSION FX(5),WTX(5)
      IF(JTYPE.EQ.2) GO TO 1
      WATE=WTX(LBAND)
      RETURN
    1 IF(FX(LBAND).LT.0.0001) GO TO 2
      WATE=WTX(LBAND)/TEMP
      RETURN
    2 WATE=WTX(LBAND)
      RETURN
      END
C
C
C
      SUBROUTINE ERROR
      WRITE (6,1)
    1 FORMAT(' ********** ERROR IN INPUT DATA ********')
      STOP
      END
C
C
C
      SUBROUTINE REMEZ(EDGE,NBANDS)
C
C
      COMMON PI2,AD,DEV,X,Y,GRID,DES,WT,ALPHA,IEXT,NFCNS,NGRID
```

Program ASKFIR

```
      DIMENSION EDGE(20)
      DIMENSION IEXT(66),AD(65),ALPHA(65),X(66),Y(66)
      DIMENSION DES(1045),GRID(1045),WT(1045)
      DIMENSION A(66),P(65),Q(65)
      DOUBLE PRECISION PI2,DNUM,DDEN,DTEMP,A,P,Q
      DOUBLE PRECISION AD,DEV,X,Y
C
C
      ITRMAX=200
      DEVL=-1.0
      NZ=NFCNS+1
      WRITE(5,222)
  222 FORMAT(' STARTING REMEZ')
      NZZ=NFCNS+2
      NITER=0
  100 CONTINUE
      IEXT(NZZ)=NGRID+1
      NITER=NITER+1
      IF(NITER.GT.ITRMAX) GO TO 400
      DO 110 J=1,NZ
      DTEMP=GRID(IEXT(J))
      DTEMP=DCOS(DTEMP*PI2)
  110 X(J)=DTEMP
      JET=(NFCNS-1)/15+1
      DO 120 J=1,NZ
  120 AD(J)=D(J,NZ,JET)
      DNUM=0.0
      DDEN=0.0
      K=1
      DO 130 J=1,NZ
      L=IEXT(J)
      DTEMP=AD(J)*DES(L)
      DNUM=DNUM+DTEMP
      DTEMP=K*AD(J)/WT(L)
      DDEN=DDEN+DTEMP
  130 K=-K
      DEV=DNUM/DDEN
      NU=1
      IF(DEV.GT.0.0) NU=-1
      DEV=-NU*DEV
      K=NU
      DO 140 J=1,NZ
      L=IEXT(J)
      DTEMP=K*DEV/WT(L)
      Y(J)=DES(L)+DTEMP
  140 K=-K
      WRITE(5,799)
  799 FORMAT(' REMEZ CHECKPOINT 2')
      IF(DEV.GE.DEVL) GO TO 150
      CALL OUCH
      GO TO 400
  150 DEVL=DEV
      JCHNGE=0
      K1=IEXT(1)
```

Program ASKFIR

```
      NNZ=IEXT(NZ)
      KLOW=0
      NUT=-NU
      J=1
C
C     SEARCH FOR THE EXTREMAL FREQUENCIES OF THE BEST
C     APPROXIMATION
C
  200 IF(J.EQ.NZZ) YNZ=COMP
      IF(J.GE.NZZ) GO TO 300
      KUP=IEXT(J+1)
      L=IEXT(J)+1
      NUT=-NUT
      IF(J.EQ.2) Y1=COMP
      COMP=DEV
      IF(L.GE.KUP) GO TO 220
      WRITE(5,596)
  596 FORMAT(' WE GOT TO HERE')
      ERR=GEE(L,NZ)
      ERR=(ERR-DES(L))*WT(L)
      DTEMP=NUT*ERR-COMP
      WRITE(5,8888)ERR,DES(L),WT(L),COMP,DTEMP,NUT,GEE(L,NZ)
 8888 FORMAT(5F10.4,I8,F10.4)
      IF(DTEMP.LE.0.0) GO TO 220
      COMP=NUT*ERR
  210 L=L+1
      IF(L.GE.KUP) GO TO 215
      ERR=GEE(L,NZ)
      ERR=(ERR-DES(L))*WT(L)
      DTEMP=NUT*ERR-COMP
      IF(DTEMP.LE.0.0) GO TO 215
      COMP=NUT*ERR
      GO TO 210
  215 IEXT(J)=L-1
      J=J+1
      KLOW=L-1
      JCHNGE=JCHNGE+1
      GO TO 200
  220 L=L-1
      WRITE(5,789)
  789 FORMAT(' RENEZ CHECKPOINT 3')
  225 L=L-1
      IF(L.LE.KLOW) GO TO 250
      WRITE(5,753)
  753 FORMAT(' JUMP TO GEE')
      ERR=GEE(L,NZ)
      WRITE(5,6432)
 6432 FORMAT(' COME BACK FROM GEE')
      ERR=(ERR-DES(L))*WT(L)
      DTEMP=NUT*ERR-COMP
      IF(DTEMP.GT.0.0) GO TO 230
      IF(JCHNGE.LE.0) GO TO 225
  230 COMP=NUT*ERR
      WRITE(5,975)
```

Program ASKFIR

```
995 FORMAT(' REMEZ CHECKPOINT 3.2')
235 L=L-1
    IF(L..LE.KLOW) GO TO 240
    ERR=GEE(L,NZ)
    ERR=(ERR-DES(L))*WT(L)
    DTEMP=NUT*ERR-COMP
    IF(DTEMP.LE.0.0) GO TO 240
    COMP=NUT*ERR
    GO TO 235
240 KLOW=IEXT(J)
    IEXT(J)=L+1
    J=J+1
    JCHNGE=JCHNGE+1
    GO TO 200
250 L=IEXT(J)+1
    IF(JCHNGE.GT.0) GO TO 215
255 L=L+1
    IF(L.GE.KUP) GO TO 260
    ERR=GEE(L,NZ)
    ERR=(ERR-DES(L))*WT(L)
    DTEMP=NUT*ERR-COMP
    IF(DTEMP.LE.0.0) GO TO 225
    COMP=NUT*ERR
    GO TO 210
260 KLOW=IEXT(J)
    J=J+1
    GO TO 200
300 IF(J.GT.NZZ) GO TO 320
    IF(K1.GT.IEXT(1)) K1=IEXT(1)
    IF(KNZ.LT.IEXT(NZ)) KNZ=IEXT(NZ)
    NUT1=NUT
    WRITE(5,432)
432 FORMAT(' REMEZ CHECKPOINT 3.5')
    NUT=-NU
    L=0
    KUP=K1
    COMP=YNZ*(1.00001)
    LUCK=1
310 L=L+1
    IF(L.GE.KUP) GO TO 315
    ERR=GEE(L,NZ)
    ERR=(ERR-DES(L))*WT(L)
    DTEMP=NUT*ERR-COMP
    IF(DTEMP.LE.0.0) GO TO 310
    COMP=NUT*ERR
    J=NZZ
    GO TO 210
315 LUCK=6
    GO TO 325
320 IF(LUCK.GT.9) GO TO 350
    IF(COMP.GT.Y1) Y1=COMP
    K1=IEXT(NZZ)
325 L=NGRID+1
    KLOW=KNZ
```

Program ASKFIR

```
      NUT=-NUT1
      COMP=Y1*(1.00001)
  330 L=L-1
      IF(L.LE.KLOW) GO TO 340
      ERR=GEE(L,NZ)
      ERR=(ERR-DES(L))*WT(L)
      DTEMP=NUT*ERR-COMP
      IF(DTEMP.LE.0.0) GO TO 330
      J=NZZ
      COMP=NUT*ERR
      LUCK=LUCK+10
      GO TO 235
  340 IF(LUCK.EQ.6) GO TO 370
      DO 345 J=1,NFCNS
  345 IEXT(NZZ-J)=IEXT(NZ-J)
      IEXT(1)=K1
      GO TO 100
  350 KN=IEXT(NZZ)
      DO 350 J=1,NFCNS
  360 IEXT(J)=IEXT(J+1)
      IEXT(NZ)=KN
      WRITE(5,987)
  987 FORMAT(' REMEZ CHECKPOINT 4')
      GO TO 100
  370 IF(JCHNGE.GT.0) GO TO 100
C
C     CALCULATION OF THE COEFFICIENTS OF THE BEST
C     APPROXIMATION USING THE INVERSE DISCRETE
C     FOURIER TRANSFORM
C
  400 CONTINUE
      NM1=NFCNS-1
      FSH=1.0E-06
      GTEMP=GRID(1)
      X(NZZ)=-2.0
      CN=2*NFCNS-1
      DELF=1.0/CN
      L=1
      KKK=0
      IF(EDGE(1).EQ.0.0.AND.EDGE(2*NBANDS).EQ.0.5) KKK=1
      IF(NFCNS.LE.3) KKK=1
      IF(KKK.EQ.1) GO TO 405
      DTEMP=DCOS(PI2*GRID(1))
      DNUM=DCOS(PI2*GRID(NGRID))
      AA=2.0/(DTEMP-DNUM)
      BB=-(DTEMP+DNUM)/(DTEMP-DNUM)
  405 CONTINUE
      DO 430 J=1,NFCNS
      FT=(FLOAT(J-1))*DELF
      XT=DCOS(PI2*FT)
      IF(KKK.EQ.1) GO TO 410
      XT=(XT-BB)/AA
C     ARCOS=ATAN(XT/SQRT(1.0-XT*XT))
      FT=ACOS(XT)/PI2
```

Program ASKFIR

```
C     FT=.5
  410 XE=Y(L)
      IF(YT.GT.XE) GO TO 420
      IF((XE-XT).LT.FSH) GO TO 415
      L=L+1
      GO TO 410
  415 A(J)=Y(L)
      GO TO 425
  420 IF((XT-XE).LT.FSH) GO TO 415
      GRID(1)=FT
      A(J)=GEE(1,NZ)
  425 CONTINUE
      IF(L.GT.1) L=L-1
  430 CONTINUE
      GRID(1)=GTEMP
      DDEN=PI2/CN
      DO 510 J=1,NFCNS
      DTEMP=0.0
      DNUM=(FLOAT(J-1))*DDEN
      IF(NM1.LT.1) GO TO 505
      DO 500 K=1,NM1
  500 DTEMP=DTEMP+A(K+1)*DCOS(DNUM*K)
  505 DTEMP=2.0*DTEMP+A(1)
  510 ALPHA(J)=DTEMP
      DO 550 J=2,NFCNS
  550 ALPHA(J)=2*ALPHA(J)/CN
      A(1)=ALPHA(1)/CN
      IF(KKK.EQ.1) GO TO 545
      P(1)=2.0*ALPHA(NFCNS)*BB+ALPHA(NM1)
      P(2)= 2.0*AA*ALPHA(NFCNS)
      Q(1)=ALPHA(NFCNS-2)-ALPHA(NFCNS)
      DO 540 J=2,NM1
      IF(J.LT.NM1) GO TO 515
      AA=0.5*AA
      BB=0.5*BB
  515 CONTINUE
      P(J+1)=0.0
      DO 520 K=1,J
      A(K)=P(K)
  520 P(K)=2.0*BB*A(K)
      P(2)=P(2)+A(1)*2.0*AA
      JM1=J-1
      DO 525 K=1,JM1
  525 P(K)=P(K)+Q(K)+AA*A(K+1)
      JP1=K+1
      DO 530 K=3,JP1
  530 P(K)=P(K)+AA*A(K-1)
      IF(J.EQ.NM1) GO TO 540
      DO 535 K=1,J
  535 Q(K)=-A(K)
      Q(1)=Q(1)+ALPHA(NFCNS-1-J)
  540 CONTINUE
      DO 543 J=1,NFCNS
  543 ALPHA(J)=P(J)
```

Program ASKFIR

```
  545 CONTINUE
      IF(NFCNS.GT.3) RETURN
      WRITE(5,765)
  765 FORMAT(' REMEZ CHECKPOINT 5')
      ALPHA(NFCNS+1)=0.0
      ALPHA(NFCNS+2)=0.0
      WRITE(5,566)
  566 FORMAT(' LEAVING REMEZ')
      RETURN
      END
C
C
      DOUBLE PRECISION FUNCTION D(K,N,M)
C
C     FUNCTION TO CALCULATE THE LAGRANGE INTERPOLATION COEFFICIENTS
C     FOR USE IN THE FUNCTION GEE.
C
      COMMON PI2,AD,DEV,X,Y,GRID,DES,WT,ALPHA,IEXT,NFCNS,NGRID
      DIMENSION IEXT(66),AD(66),ALPHA(66),X(66),Y(66)
      DIMENSION DES(1045),GRID(1045),WT(1045)
      DOUBLE PRECISION AD,DEV,X,Y
      DOUBLE PRECISION Q
      DOUBLE PRECISION PI2
      D=1.0
      Q=X(K)
      DO 3 L=1,M
      DO 2 J=L,N,M
      IF(Q-X(J))1,2,1
    1 D=2.0*D*(Q-X(J))
    2 CONTINUE
    3 CONTINUE
      D=1.0/D
      RETURN
      END
C
C
      DOUBLE PRECISION FUNCTION GEE(K,N)
C
C     FUNCTION TO EVALUATE THE FREQUENCY RESPONSE USING THE
C     LAGRANGE INTERPOLATION FORMULA IN THE BARYCENTRIC FORM
C
C
      COMMON PI2,AD,DEV,X,Y,GRID,DES,WT,ALPHA,IEXT,NFCNS,NGRID
      DIMENSION IEXT(66),AD(66),ALPHA(66),X(66),Y(66)
      DIMENSION DES(1045),GRID(1045),WT(1045)
      DOUBLE PRECISION P,C,D,XF
      DOUBLE PRECISION PI2
      DOUBLE PRECISION AD,DEV,X,Y
      P=0.0
      XF=GRID(K)
      XF=DCOS(PI2*XF)
      D=0.0
      DO 12 J=1,N
      C=XF-X(J)
```

Program ASKFIR

```
C      WRITE (5,6666) XF,X(J)
       IF (C) 4,12,4
    4  CONTINUE
C6666 FORMAT(2F10.5)
       C=AD(J)/C
       D=D+C
    1  P=P+C*Y(J)
   12  CONTINUE
       IF(D) 33.66,33
   33  CONTINUE
       GEE=P/D
       GO TO 77
   66  CONTINUE
       GEE=.5
   77  CONTINUE
       RETURN
       END
C
C
       SUBROUTINE OUCH
       WRITE (6,111)
  111  FORMAT(' **********FAILURE TO CONVERGE**********')
C     1' PROBABLE CAUSE IS MACHINE ROUNDING ERROR',
C     2' THE IMPULSE RESPONSE MAY BE CORRECT',
C     3' CHECK WITH A FREQUENCY RESPONSE')
       RETURN


       END
```

Program ASKFIR

APPENDIX E

Program Listing: DELAY13.FTN

This is a sample of a variable time delay filter. It has unity gain for all frequencies (up to frequencies near the sample frequency) and has a time delay which is progressively less for higher frequencies. It runs in an interactive mode on the pdp 11/45.

```
FORTRAN IV-PLUS V02-51          11:32:49    28-APR-78          PAGE 1
DELAY13.FTN     /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2),ISB(2)
                C
                C       THIS PROGRAM SYNTHESIZES AND EXECUTES
                C       A DIGITAL FILTER WHICH HAS UNITY GAIN AT
                C       ALL FREQUENCIES BUT THE TIME DELAY IS
                C       LESS FOR HIGHER FREQUENCIES.  THE IDEA IS
                C       TO PROVIDE SOME LEAD FOR THE ISOPAD CONTROL.
                C
                C
                C
0002            WRITE(5,80)
0003         80 FORMAT('$ ENTER TIME DELAY MULTIPLIER-FLT.PT.  ')
0004            READ (5,81) FREQ
0005         81 FORMAT(F10.7)
0006            IFREQ=FREQ
                C
                C       READ IN SAMPLE PERIOD IN MILLISECONDS
0007            WRITE (5,30)
0008         30 FORMAT('$ ENTER SAMPLE PERIOD IN MILLISECONDS-INTEGER   ')
0009            READ (5,31) IRATE(2)
0010         31 FORMAT (I6)
                C
                C       INITIALIZE FILTER
                C
                C
0011            Y=0.0
                C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0012            CALL ASLUN(1,ISB)
                C
                C       DESIG   OUTPUT DAC CHANNEL FOR DATEL 256
0013            ICHP
                C
                C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0014            IEFN=7
                C
                C
                C       PUT LPS11 RTS ROUTINE IN MILLISEC % SAMPLING MODE
0015            IRATE(1)=2
                C
                C
                C       INITIATE SYNCHRONOUS SAMPLING
0016         90 CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
                C
0017            INDX=5
0018         10 CALL WAITFR(IEFN)
0019         15 CALL CLRFLG(IEFN)
0020            SIGNA=IBUF(INDX)
                C
```

```
   TRAN IV-PLUS V02-                    12:49     28-APR-78          PAGE 2
DELAY13.FTN      /TR:BLOCK I/O

        C      SCALE IN VOLTS
0021            IDATA=10000.*(SIGNA/2048.)-10000.
        C
        C      BEGIN FILTER ROUTINE
0022            IDIFF=IABS(IDATA2-IDATA)
0023            IF(IDIFF.LT.IFREQ) IDIFF=0
0024            DIFF=IDIFF
        C
0025            DLEEP=2*DLEEP-DLEEP
0026            BLAP=0.
0027            DLEEP=DLEEP+BLEEP
0028            IDATA2=IDATA
0029            IDATA2=IDATA
0030            IDELAY=IFREQ*IDELAY
0031            IF(IDELAY.LT.2) GO TO 9977
0032            DO 9977 I=1,IDELAY
0033            BLAP=1.
        C       WASTE=SIN(BLAP)
        C       WASTE=COS(BLAP)
0034     9977   CONTINUE
        C       CALL LPS11 LED DISPLAY ROUTINE
0035            CALL LED(IDATA)
        C
        C       CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0036            CALL IDAC(ICHAN,IDATA)
        C
        C       ADJUST POINTERS FOR LPS11
        C       AND CLEAR HALF BUFFER FOR NEXT SAMPLE
0037            CALL   DJLP.
        C
0038            INDX=INDX+
        C
        C       CHECK STATUS REGISTER FOR PROPER I/O
        C       AND TERMINATE IF STATUS NOT CORRECT
0039            IF (INDX.GT.5) INDX=5
0040            IF (IS2(2).GE.1) GO TO 10
0041            IF (IS3(1).NE.0) GO TO 95
0042            GO TO 10
0043     95     CONTINUE
        C
        C       IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0044            WRIT.  ,20.   IS8(1),IS2(2),IDATA,IBUF(INDX)
0045     200    FORMAT(4I12)
0046     195    CONTINUE
0047            END


PROGRAM SECTIONS
```

```
FORTRAN IV-PLUS V02-51          11:32:49    28-APR-78          PAGE 3
DELAY13.FTN     /TR:BLOCKS/WR


 NAME        SIZE                ATTRIBUTES

$CODE1   000716   231             RW,I,CON,LCL
$PDATA   000020     8             RW,D,CON,LCL
$IDATA   000226    75             RW,D,CON,LCL
$VARS    000076    31             RW,D,CON,LCL
$TEMPS   002002     1             RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 001264   345

.DELAY13=DELAY13
```

APPENDIX F

Program Listings: BAD.FTN, BAND.FTN, NINE9.FTN, DIFF32.FTN

These programs all execute FIR filters on the pdp 11/45.

```
FORTRAN IV-PLUS V02-F1          11:11:36    28-APR-78          PAGE 1
SAD.FTN          /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2),ISB(2),H(30),Y(60)
        C
        C       THIS PROGRAM SYNTHESIZES AND EXECUTES
        C       LINEAR PHASE FINITE IMPULSE RESPONSE FILTER
        C       WITH COEFFICIENTS GENERATED USING THE REMEZ
        C       EXCHANGE ALGORITHM.
        C
        C       IT IS A SPECIAL MODIFICATION OF EASY.FTN
        C       FOR THE CASES WHERE N=AN ODD INTEGER
        C
        C
        C       SET ORDER OF FILTER (CAN BE EVEN OR ODD AND EQUAL
        C       TO NUMBER OF H COEFFICIENTS
0002            N=9
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0006            H(1)=-.54497945
0007            H(2)=-.20219856
0008            H(3)=-.59043782
0009            H(4)=.32028612
0010            H(5)=.55136021
        C
        C
        C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0011            CALL ASLSLN (1,ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0012            ICHAN=0
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0013            IEFN=7
        C
        C       SPECIFY TIME BETWEEN SAMPLES IN MILLISECONDS
0014            IRATE(2)=100
        C
        C       PUT LPS11 PTT ROUTINE IN MILLISECOND SAMPLING MODE
0015            IRATE(1)=3
        C
        C
        C       CALCULATE SAMPLE INTERVAL IN SECONDS
0016            ST=FLOAT(IRATE(2))/1000.
        C
```

```
C
C
C
C     INITIATE SYNCHRONOUS SAMPLING
*0017 90    CALL RTS(IBUF,6,0,RATE,IFIN,0,1,ISB)
C
0018        INDX=5
0019 10     CALL WAITFR(IEFN)
*0020 15    CALL CLRSF(IEFN)
0021        SIGNA=IBUF(INDX)
C
C     SCALE IN VOLTS
0022        Y(1)=10000.*(SIGNA/2049.)-10000.
C
C     BEGIN FILTER ROUTINE
0023        DO 544 I=1,N-1
0024        Y(I+1)=Y(I)
0025 544     CONTINUE
C
0026        SUM=0.0
0027        DO 20 I=1,N/2
0028        TERM=H(I)*(Y(I)+Y(N-I+1))
0029        SUM=SUM +TERM
0030 20     CONTINUE
0031        TERM=H(N/2+1)*Y(N/2+1)
0032        SUM=SUM+TERM
0033        IDATA=SUM
C     CALL LPS11 LED DISPLAY ROUTINE
0034        CALL LED(IDATA)
C
C     CALL ROUTINE TO OUTPUT RESULT TO DATEL 255
*035        CALL IDAC(CHAN,IDATA)
C
C     ADJUST POINTERS FOR LPS 1
C     AND CLEAR A/D BUFFER FOR NEXT SAMPLE
0036        CALL  ADJLPS(IBUF,1)
C
0037        INDX=INDX+1
C
C     CHECK STATUS REGISTER FOR PROPER I/O
C     AND TERMINATE IF STATUS NOT CORRECT
0038        IF (INDX.GT.6) INDX=5
0039        IF (ISB(2).GE.1) GO TO 95
0040        IF (ISB(1).NE.0) GO TO 95
0041        GO TO 10
0042 95     CONTINUE
C
C     IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
```

```
FORTRAN IV-PLUS V02-51          11:11:36    28-APR-78          PAGE 3
BAD.FTN          /TR:BLOCKS/WD

0043           WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0044     200   FORMAT(4I12)
0045     195   CONTINUE
0046           END


PROGRAM SECTIONS

 NAME      SIZE                  ATTRIBUTES

$CODE1  000732   237             RW,I,CON,LCL
$PDATA  000044    18             RW,D,CON,LCL
$IDATA  000060    24             RW,D,CON,LCL
%VARS   000630   204             RW,D,CON,LCL
$TEMPS  000002     1             RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 001710   484

.BAD=BAD
```

```
FORTRAN IV-PLUS V02-51          11:14:24    28-APR-78          PAGE 1
BAND.FTN        /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2),ISB(2),H(30),Y(60)
        C
        C       THIS PROGRAM SYNTHESIZES AND EXECUTES
        C       LINEAR PHASE FINITE IMPULSE RESPONSE FILTER
        C       WITH COEFFICIENTS GENERATED USING THE REMEZ
        C       EXCHANGE ALGORITHM.
        C
        C
        C       SET ORDER OF FILTER (MUST BE EVEN AND EQUAL
        C       TO NUMBER OF H COEFFICIENTS
0002            N=32
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            Y(I)=0.0
0004            DO 299 I=1,N
0005    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0006            H(1)=-0.57534121E-02
0007            H(2)=0.99027100E-03
0008            H(3)=0.75733545E-02
0009            H(4)=-0.65141192E-02
0010            H(5)=0.13830525E-01
0011            H(6)=0.22951469E-02
0012            H(7)=-0.1039406?E-01
0013            H(8)=0.?13685?0E-02
0014            H(9)=-0.?26573?2E-01
0015            H(10)=0.11260114E-01
0016            H(11)=0.662336?3E-01
0017            H(12)=-0.10497223E-01
0018            H(13)=0.851361?3E-01
0019            H(14)=-0.1???????E 00
0020            H(15)=-0.29578577E 00
0021            H(16)=0.?9?1917E 00
        C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0022            CALL ASLSLN (1,ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL ???
0023            ICHAN=0
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0024            IEFN=7
        C
        C       SPECIFY TIME BETWEEN SAMPLES IN MILLISECS  ?
0025            IRATE(2)=100
        C
        C       PUT LPS11 PTS ROUTINE IN MILLISECOND SAMPLE MODE
```

```
FORTRAN IV-PLUS V02-51          11:14:24    28-APR-78          PAGE 2
BAND.FTN        /TR:BLOCKS/WR

0326            IRATE(1)=2
        C
        C
        C       CALCULATE SAMPLE INTERVAL IN SECONDS
0027            ST=FLOAT(IRATE(2))/1000.
        C
        C
        C
        C
        C       INITIATE SYNCHRONOUS SAMPLING
*028    90      CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,I33)
        C
*029            INDX=5
*030    10      CALL WAITFR(IEFN)
*031    15      CALL CLREF(IEFN)
*032            SIGMA=IBUF(INDX)
        C
        C       SCALE IN VOLTS
*033            Y(1)=10000.*(SIGMA/2048.)-10000.
        C
        C       BEGIN FILTER ROUTINE
0034            DO 544 I=1,N-1
0035            Y(I+1)=Y(I)
0036    544     CONTINUE
        C
*037            SUM=0.0
*038            DO 20 I=1,N
*039            TERM=H(I)*(Y(I)+Y(N-I+1))
*040            SUM=SUM +TERM
 041    20      CONTINUE
*042            IDATA=SUM
        C       CALL LPS11 LED DISPLAY ROUTINE
0043            CALL LED(IDATA)
        C
        C       CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0044            CALL IDAC(ICHAN,IDATA)
        C
        C       ADJUST POINTERS FOR LPS11
        C       AND CLEAR HALF BUFFER FOR NEXT SAMPLE
*045            CALL  ADJLPS(IBUF,1)
        C
*046            INDX=INDX+1
        C
        C       CHECK STATUS REGISTER FOR PROPER I/O
        C       AND TERMINATE IF STATUS NOT CORRECT
*047            IF (INDX.GT.6) INDX=5
*048            IF (ISB(2).GE.1) GO TO 10
 048            IF (ISB(1).NE.0) GO TO 95
```

```
FORTRAN IV-PLU   /02-51           11:14:24    28-APR-78            PAGE 3
BAND.FTN          /IP:BLOCKS/

0050            CO  10 10
0051     95     C   INUE
         C
         C      IF  ROGRAM CHANGES PRINT STATUS ON WAY OUT
0052            W   TE  (5,200)  ISB(1), ISB(2), IDATA, IBUF(INDX)
0053     200    F    AT(4I12)
0054     195    C    INUE
0055            E


PROGRAM SECTION

 NAME        SIZE                       ATTRIBUTES

$CODE1   001046    275           RW,I,CON,LCL
$PDATA   000120     40           RW,D,CON,LCL
$IDATA   000060     24           RW,D,CON,LCL
$VARS    000630    204           RW,D,CON,LCL
$TEMPS   000002      1           RW,D,CON,LCL

TOTAL SPACE ALLO    ED = 00210    544

  ND=BAND
```

```
FORTRAN IV-PLUS V02-51          11:02:30    28-APR-78          PAGE 1
MINES.FTN       /TR:BLOCKS/LR

0001            DIMENSION IBUF(6),IRATE(2),ISB(2),H(30),Y(60)
        C
        C       THIS PROGRAM SYNTHESIZES AND COMPUTES
        C       LINEAR PHASE FINITE IMPULSE RESPONSE FILTER
        C       WITH COEFFICIENTS GENERATED USING THE REMEZ
        C       EXCHANGE ALGORITHM.
        C
        C       IT IS A SPECIAL MODIFICATION OF EASY.FTN
        C       FOR THE CASES WHERE N=AN ODD INTEGER
        C
        C
        C       SET ORDER OF FILTER (CAN BE EVEN OR ODD AND EQUAL
        C       TO NUMBER OF H COEFFICIENTS
0002            N=9
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0006            H(1)=-.54[illegible]7945
0007            H(2)=-.2031985[illegible]
0008            H(3)=-.5804[illegible]
0009            H(4)=.3202861[illegible]
0010            H(5)=.53120021
        C
        C
        C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0011            CALL [illegible]LN [illegible],ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR INTEL 255
0012            ICHAN=3
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0013            IEFN=[illegible]
        C
        C
0014            WRITE (5,80)
0015       80   FORMAT(' CUTOFF FREQ. IS 0.25 TIME SAMPLE FREQ. ')
0016            WRITE (5,81)
0017       81   FORMAT('$ ENTER SAMPLE PERIOD IN MILLISECONDS-INTEGER: ')
0018            READ (5,82)
0019       82   FORMAT (I6)
        C       PUT LPS11 RTS ROUTINE IN MILLISECOND SAMPLING MODE
0020            IRATE(1)=2
        C
```

```
FORTRAN IV-PLUS V02-01          11:32:30    28-APR-78          PAGE 2
NINE9.FTN       /TR:BLOCKS/WR

        C
        C     CALCULATE SAMPLE INTERVAL IN SECONDS
0021            ST=FLOAT(IRATE(2))/1000.
        C
        C
        C
        C
        C     INITIATE SYNCHRONOUS SAMPLING
0022    90      CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
        C
0023            INDX=5
0024    10      CALL WAITFR(IEFN)
0025    15      CALL CLREF(IEFN)
0026            SIGMA=IBUF(INDX)
        C
        C     SCALE IN VOLTS
0027            Y(I)=10000.*(SIGMA/2048.)-10000.
        C
        C     BEGIN FILTER ROUTINE
0028            DO 544 I=1,N-1
0029            Y(I+1)=Y(I)
0030    544      CONTINUE
        C
0031            SUM=0.0
0032            DO 20 I=1,N/2
0033            TERM=A(I)*(Y(I)+Y(N-I+1))
0034            SUM=SUM+TERM
0035    20      CONTINUE
0036            TERM=.5(N/2+1)*Y(N/2+1)
0037            SUM=SUM+TERM
0038            IDATA=SUM
        C     CALL LPS11 LED DISPLAY ROUTINE
0039            CALL LED(IDATA)
        C
        C     CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0040            CALL DAC(ICHAN,IDATA)
        C
        C     ADJUST POINTERS FOR LPS11
        C     AND RELOAD HALF BUFFER FOR NEXT SAMPLE
0041            CALL ADLPS(IBUF,1)
        C
0042            IF(INDX.EQ.5) INDX=11
        C
        C     CHECK FOR ERROR AFTER FOR PROPER I/O
        C     AND TERMINATE IF I/O WAS NOT CORRECT
0043            IF (INDX.GT.6) INDX=5
0044            IF (ISB(2).GE.1) GO TO 10
0045            IF (ISB(1).NE.0) GO TO 95
```

```
FORTRAN IV-PLUS V02-51          11:32:30    28-APR-78          PAGE 3
NINE9.FTN       /TP:BLOCKS/WR

0046            GO TO 10
0047     95     CALL EXIT
         C
         C      IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0048            WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0049     200    FORMAT (1X,4I6)
0050     195    CONTINUE
0051            END


PROGRAM SECTIONS

 NAME        SIZE                    ATTRIBUTES

.CODE1   001004   258          RW,I,CON,LCL
.PDATA   000044    18          RW,D,CON,LCL
$IDATA   000202    73          RW,D,CON,LCL
SWAPS    000630   204          RW,D,CON,LCL
$TEMPS   000002     1          RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 002124   554

.NINC9=NINE9
```

```
FORTRAN IV-PLUS V02-51          11:33:16    [illegible]          PAGE 1
[illegible].FTN      /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2,[illegible]),Y(60)
        C
        C       THIS PROGRAM SYNTHESIZES AN E [illegible]
        C       LINEAR PHASE FINITE IMPULSE RESPONSE FILTER
        C       WITH COEFFICIENTS GENERATED USI[illegible] THE REMEZ
        C       EXCHANGE ALGORITHM.
        C
        C
        C       SET ORDER OF FILTER (MUST BE EVEN AND EQUAL
        C       TO NUMBER OF H COEFFICIENTS
0002            N=32
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            Y(1)=0.0
0004            DO 299 I=1,N
0005    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0006            H(1)=-0.[illegible]4121E-02
0007            H(2)=0.9[illegible]7198E-03
0008            H(3)=0.75[illegible]3545E-02
0009            H(4)=-0.6[illegible]1[illegible]3E-02
0010            [illegible]
0011            [illegible]
0012            H(7)=-0.1[illegible]
0013            H(8)=0.71[illegible]
0014            H(9)=-0.39[illegible]
0015            H(10)=0.11[illegible]
0016            H(11)=0.66[illegible]
0017            H(12)=-0.1[illegible]
0018            H(13)=0.8[illegible]
0019            H(14)=-0.1[illegible]
0020            H(15)=-0.2[illegible]
0021            H(16)=0.3[illegible]
        C       INITIALIZE [illegible] PERIPHERAL INTERFACE
0022            CALL ASLSLN (1,IER)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR LEVEL 256
0023            ICHAN=0
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0024            IEFN=7
        C
        C       SPECIFY TIME BETWEEN SAMPLES IN MILLISECONDS
0025            IRATE(2)=100
        C
        C       PUT LPS11 RTS ROUTINE IN MULTIPLE D/A SAMPLING MODE
```

```
[illegible]26          IRATE[illegible]
                C
                C
                C       CALCUL[illegible]PL IN SECOND
[illegible]27           ST=FLO[illegible]
                C
                C
                C
                C
                C       INI[illegible]G
[illegible]28   90      CALL [illegible],0,[illegible],IEFN,0,1,ISB)
                C
[illegible]29           INDX=3
[illegible]30   10      CALL [illegible]IEFN)
[illegible]31   15      CALL [illegible]IEFN)
[illegible]32           SIGN=[illegible]
                C
                C       SCALE[illegible]
[illegible]33           Y(1[illegible]*1000/2048.)-10000.
                C
                C       BEG[illegible]
[illegible]34           DO 5[illegible]
[illegible]35           Y(I+1[illegible]
[illegible]36   544      CONT[illegible]
                C
[illegible]37           SUM=0.0
[illegible]38           DO 2[illegible]
[illegible]39           TEM[illegible]Y(I)-Y(I+1))
[illegible]40           SUM=[illegible]
[illegible]41   20      CONT[illegible]
[illegible]42           IRATE=[illegible]
                C       CALL [illegible]ED DISPLAY ROUTINE
[illegible]43           CALL [illegible]
                C
                C       CALL [illegible]E TO OUTPUT RESULT TO DATA 256
[illegible]44           CALL [illegible](IFN,IDATA)
                C
                C       ADJUST [illegible]TIPS FOR LPS11
                C       AND CL[illegible]E BUFFER FOR NEXT SAMPLE
[illegible]45           CALL [illegible](IBUF,1)
                C
[illegible]46           INI=[illegible]
                C
                C       CHECK [illegible]S REGISTER FOR PROPER I/O
                C       AND [illegible]E IF STATUS NOT CORRECT
[illegible]47           IF ([illegible]INDX+5
[illegible]48           IF [illegible]1) GO TO 10
[illegible]49           IF ([illegible]2.0) GO TO 11
```

```
FORTRAN IV-PLUS V02-51          11:57:16    28-APR-78          PAGE 3
DIFF32.FTN      /TR:BLOCKS/WR

0050            GO TO 10
0051     95     CONTINUE
         C
         C      IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0052            WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0053     200    FORMAT(4I12)
0054     195    CONTINUE
0055            END


PROGRAM SECTIONS

 NAME        SIZE                    ATTRIBUTES

$CODE1   001046   275                RW,I,CON,LCL
$PDATA   000120    40                RW,D,CON,LCL
$IDATA   000060    24                RW,D,CON,LCL
$VARS    000630   204                RW,D,CON,LCL
$TEMPS   000002     1                RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 002100   544




 DIFF32=DIFF32
```

APPENDIX G

Program Listings: CASE8.FTN, CASE8F.FTN, HONEYF.FTN, and BUTTER.FTN

These programs all execute IIR filters on the pdp 11/45 with coefficients from the MAS/FIL program.

```
FORTRAN IV-PLUS V02-51          11:32:12    28-APR-78          PAGE 1
DSP8.FTN        /TR:BLOCKS/WR

0001            DIMENSION ICOF(6),IRATE(2),ISB(2),H(20),Y(20),X(20),G(20)
                C
                C       THIS PROGRAM SYNTHESIZES AND EXECUTES
                C       AN INFINITE IMPULSE RESPONSE FILTER WITH COEFFICIENTS
                C       GENERATED BY THE IIRFIL PROGRAM.  THE FILTERING LOOP
                C       IS FOR THE CASE WHERE THERE IS ONLY ONE NON-RECURSIVE
                C       WEIGHT AND FOUR RECURSIVE WEIGHTS.
                C
                C
                C       N IS THE NUMBER OF RECURSIVE WEIGHTS
0002            N=8
                C
                C
                C
                C       INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005            X(I)=0.0
0006    299     CONTINUE
                C
                C       SET H COEFFICIENTS
0007            H(1)= 7.4013016
0008            H(2)=-24.070298
0009            H(3)= 44.926980
0010            H(4)=-52.639065
0011            H(5)= 39.6[illegible]5219
0012            H(6)=-18.74[illegible]984
0013            H(7)=  5.00[illegible]574
0014            H(8)=  -.9[illegible]15
                C
                C
                C       SET G COEFFICIENT
0015            G(0)= .0014[illegible]51
0016            G(1)=-.0087154955
0017            G(2)= .023574271
0018            G(3)=-.039814594
0019            G(4)= .0[illegible]916724
0020            G(5)=G(3)
0021            G(6)=G(2)
0022            G(7)=G(1)
0023            G(8)=G(0)
                C
                C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0024            CALL ADLSLN (1,ISB)
                C
                C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 255
0025            ICHAN=0
                C
```

```
FORTRAN IV-PLUS V02-[illegible]          11:32:12    28-APR-78           PAGE 2
[illegible].FTN        /TR:BLOCKS/[illegible]

              C
              C       DESIGNATE [illegible] LPS11 FLAG SET
0023                  IEFN=7
              C

              C
              C       READ IN SAMPLE PERIOD IN MILLISECONDS
0027                  WRITE (5,30)
0028               30 FORMAT('$ENTER SAMPLE PERIOD IN SECONDS-INTEGER   ')
0029                  READ (5,31) IRATE(2)
0030               31 FORMAT (I6)
              C
              C       PUT LPS11 RTS ROUTINE IN SECONDS SAMPLING MODE
0031                  IRATE(1)=3
              C
              C
              C
              C
0032          90      CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
0033                  INDX=5
0034          10      CALL WAITFR(IEFN)
0035          15      CALL CLREF(IEFN)
0036                  SIGMA=IBUF(INDX)
              C
              C       SCALE IN VOLTS
0037                  X(0)=10000.*(SIGMA/2048.)-10000.
              C
              C
0038                  SUM=0.0
0039                  DO 20 I=1,N
0040                  TERM[illegible]I)*Y(I)

0041                  SU[illegible]
0042          20      CO[illegible]
0043                  SUM[illegible]
0044                  [illegible]
0045                  [illegible]
0046                  [illegible]
0047                  S[illegible]
0048               99 CON[illegible]
0049                  SUME=SU[illegible]2)
0050                  Y(1)=SUM[illegible]
0051                  IDATA=500.*Y(1)

0052                  WRITE(5,345) SUM,SUME,Y(1),TERM,TURM
0053              345 FORMAT (5F10.3)
              C
              C       SAVE RECURSIVE TERMS
```

```
*.FTRAN IV-PLUS V02-51          11:32:12    28-APR-78          PAGE 3
*.E8.FTN       /TR:BLOCKS/LR

0054            DO 544 I=0,N
0055            Y(I+2)=Y(I+1)
0056            X(I+1)=X(I)
0057          544 CONTINUE
              C
              C     CALL LPS11 LED DISPLAY ROUTINE
0058            CALL LED(IDATA)
              C
              C     CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0059            CALL IDA[illegible](IDATA)
              C
              C     ADJUST POINTERS FOR LPS11
              C     AND CLEAR [illegible] FOR NEXT SAMPLE
0060            C[illegible]
              C
0061            [illegible]
              C
              C     CHECK [illegible] REGISTER FOR PROPER I/O
              C     AND TO [illegible] STATUS NOT CORRECT
0062            IF (IN[illegible]
0063            IF (ISB(2).NE.1[illegible]0 10
0064            IF (ISB(1).NE.0[illegible]0 95
0065            GO TO 10
0066      95    CONTINUE
              C
              C     IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0067            WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0068      200   FORMAT(4I12)
0069      195   CONTINUE
0070            END


PROGRAM SECTIONS

 NAME        SIZE                  ATTRIBUTES

$CODE1   001330   364             RW,I,CON,LCL
$DATA    000104    34             RW,D,CON,LCL
$IDATA   000150    52             RW,D,CON,LCL
%VARS    000566   187             RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 002372   637

.CASE8=CASE8
```

```
FORTRAN IV-PLUS V02-51          11:13:18    28-APR-78          PAGE 1
CASE8F.FTN      /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IRATE(2),IS8(2),H(20),Y(20),X(20),G(20)
        C
        C       THIS PROGRAM SYNTHESIZES AND EXECUTES
        C       AN INFINITE IMPULSE RESPONSE FILTER WITH COEFFICIENTS
        C       GENERATED BY THE MACFIL PROGRAM.  THE FILTERING LOOP
        C       IS FOR THE CASE WHERE THERE IS ONLY ONE NON-RECURSIVE
        C       WEIGHT AND FOUR RECURSIVE WEIGHTS.
        C
        C
        C       N IS THE NUMBER OF RECURSIVE WEIGHTS
0002            N=8
        C
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005            X(I)=0.0
0006    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0007            H(1)= 7.4013016
0008            H(2)=-24.070098
0009            H(3)= 44.926980
0010            H(4)=-52.639065
0011            H(5)= 39.645219
0012            H(6)=-18.744094
0013            H(7)=  5.0865574
0014            H(8)=  -.60660115
        C
        C
        C       SET G COEFFICIENTS
0015            G(0)= .001497[illegible]361
0016            G(1)=-.008[illegible]755
0017            G(2)= .00[illegible]
0018            G(3)=-.03[illegible]
0019            G(4)= .04[illegible]
0020            G(5)=G(3)
0021            G(6)=G(2)
0022            G(7)=G(1)
0023            G(8)=G(0)
        C
        C       INITIALIZE LABORATORY PERIPHERAL SYSTEM
0024            CALL ASSIGN (7,ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0025            ICHAN=0
        C
```

```
FORTRAN IV-PLUS V02-51          11:13:18    29-APR-78          PAGE 2
CASE8F.FTN      /TR:BLOCKS/WR

        C
        C     DESIGNATE REGISTER FOR LPS11 FLAG SET
0026            IEFN=7
        C
        C
        C
        C     READ IN SAMPLE PERIOD IN MILLISECONDS
0027            WRITE (5,30)
0028         30 FORMAT('$ENTER SAMPLE PERIOD IN MILLISECONDS-INTEGER   ')
0029            READ (5,31) IRATE(2)
0030         31 FORMAT (I5)
        C
        C     PUT LPS11 RTS ROUTINE IN MILLISECONDS SAMPLING MODE
0031            IRATE(1)=2
        C
        C
        C
        C
0032     90     CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
0033            INDX=5
0034     10     CALL WAITFR(IEFN)
0035     15     CALL CLRLF(IEFN)
0036            SIGNA=IBUF(INDX)
        C
        C     SCALE IN VOLTS
0037            X(0)=10000.*(SIGNA/2048.)-10000.
        C
        C
0038            SUM=0.0
0039            DO 20 I=1,N
0040            TERM=H(I)*Y(I)

0041            SUM=SUM +TERM
0042     20     CONTINUE
0043            SUME=0.0
0044            NN=(N/2)-1
0045            DO 99 I=0,NN
0046            TURM=G(I)*(X(I)+X(N-I))
0047            SUME=SUME+TURM
0048         99 CONTINUE
0049            SUME=SUME+G(N/2)*X(N/2)
0050            Y(1)=SUM+SUME
0051            IDATA=500.*Y(1)

0052            WRITE(5,345) SUM,SUME,Y(1),TERM,TURM
0053        345 FORMAT (5F10.3)
        C
        C     SAVE PRECURSIVE TERMS
```

```
 LPTRAN IV-PLUS V02-51          11:13:18    09-SEP-78          PAGE 3
CASE8F.FTN      /TR:BLOCKS/WR

0054           DO 544 I=0,N
0055           Y(I+2)=Y(I+1)
0056           X(I+1)=X(I)
0057       544 CONTINUE
       C
       C   CALL LPS11 LED DISPLAY ROUTINE
0058           CALL LED(IDATA)
       C
       C      CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0059           CALL IDAC(ICHAN,IDATA)
       C
       C      ADJUST POINTERS FOR LPS11
       C      AND CLEAR HALF BUFFER FOR NEXT SAMPLE
0060           CALL  ADJLPS(IBUF,1)
       C
0061           INDX=INDX+1
       C
       C      CHECK STATUS REGISTER FOR PROPER I/O
       C      AND TERMINATE IF STATUS NOT CORRECT
0062           IF (INDX.GT.6) INDX=5
0063           IF (ISB(2).GE.1) GO TO 10
0064           IF (ISB(1).NE.0) GO TO 95
0065           GO TO 10
0066       95  CONTINUE
       C
       C      IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
0067           WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
0068       200 FORMAT(4I12)
0069       195 CONTINUE
0070           END


PROGRAM SECTIONS

 NAME        SIZE                 ATTRIBUTES

$CODE1   001330   364             RW,I,CON,LCL
$PDATA   000104    34             RW,D,CON,LCL
$IDATA   000154    54             RW,D,CON,LCL
$ WRS    000566   187             RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 002376   639

.CASE8F=CASE8F
```

```
FORTRAN IV-PLUS V02-51          11:14:39    28-APR-78          PAGE 1
^ONEYF.FTN      /TR:BLOCKS/WP

0001            DIMENSION IBUF(6),IRATE(2),ISB(2),H(30),Y(60)
                C
                C     THIS PROGRAM SYNTHESIZES AND EXECUTES
                C     AN INFINITE IMPULSE RESPONSE FILTER WITH COEFFICIENTS
                C     GENERATED BY THE MACFIL PROGRAM.  THE FILTERING LOOP
                C     IS FOR THE CASE WHERE THERE IS ONLY ONE NON-RECURSIVE
                C     WEIGHT AND FOUR RECURSIVE WEIGHTS.
                C
                C
                C     N IS THE NUMBER OF RECURSIVE WEIGHTS
0002            N=5
                C
                C
                C
                C     INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005    299     CONTINUE
                C
                C     SET H COEFFICIENTS
0006            H(1)=.92479991
0007            H(2)=-.68504853
0008            H(3)=.30071078
0009            H(4)=-.11483219
0010            H(5)=.03304264
                C
                C
                C     SET G COEFFICIENT
0011            G=.52271373
                C
                C     INITIALIZE LABORATORY PERIPHERAL SYSTEM
0012            CALL ASLSLN (1,ISB)
                C
                C     DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0013            ICHAN=0
                C
                C     DESIGNATE REGISTER FOR LPS11 FLAG SET
0014            IEFN=7
                C
                C     READ IN SAMPLE PERIOD IN MILLISECONDS
0015            WRITE (5,30)
0016         30 FORMAT('$ENTER SAMPLE PERIOD IN MILLISECONDS-INTEGER   ')
0017            READ (5,31) IRATE(2)
0018         31 FORMAT (I6)
                C
                C
                C     PUT LPS11 RTS ROUTINE IN SECONDS SAMPLING MODE
0019            IRATE(1)=2
```

```
FORTRAN IV-PLUS V02-51          11:14:39     28-SEP-78          PAGE 2
 NEYF.FTN       /TR:BLOCKS/WR

                C
                C
                C
                C
0020            90      CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
0021                    INDX=5
0022            10      CALL WAITFR(IEFN)
0023            15      CALL CLOSEF(IEFN)
0024                    SIGMA=IBUF(INDX)
                C
                C       SCALE IN VOLTS
0025                    X=10000.*(SIGMA/2048.)-10000.

                C
                C
0026                    SUM1=0.0
0027                    DO 20 I=1,N
0028                    TERM1=H(I)*Y(I)

0029                    SUM1=SUM1 +TERM
0030            20      CONTINUE
0031                    Y(1)=SUM1+G*X
0032                    IDATA=Y(1)
                C
                C       SAVE RECURSIVE TERMS
0033                    DO 544 I=1,N-1
0034                    Y(I+1)=Y(I)
0035              544   CONTINUE
                C
                C       CALL LP11 LED DISPLAY ROUTINE
0036                    CALL LED(IDATA)
                C
                C       CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
0037                    CALL IOPC(ICHAN,IDATA)
                C
                C       ADJUST POINTERS FOR LPS11
                C       AND CLEAR HALF BUFFER FOR NEXT SAMPLE
0038                    CALL  ADJLPS(IBUF,1)
                C
0039                    INDX=INDX+1
                C
                C       CHECK STATUS REGISTER FOR PROPER I/O
                C       AND TERMINATE IF STATUS NOT CORRECT
0040                    IF (INDX.GT.5) INDX=5
0041                    IF (ISB(2).GE.1) GO TO 10
0042                    IF (ISB(1).NE.0) GO TO 95
0043                    GO TO 10
0044            95      CONTINUE
```

```
FORTRAN IV-PLUS V02-51          11:14:39    28-APR-78          PAGE 3
HONEYF.FTH      /TR:BLOCKS/WR

        C
        C       IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
3045            WRITE (5,200) ISB(1),ISB(2),IDATA,IBUF(INDX)
3046    200     FORMAT(4I12)
3047    195     CONTINUE
3048            END


PROGRAM SECTIONS

 NAME        SIZE                    ATTRIBUTES

$CODE1  000740   240                  RW,I,CON,LCL
$PDATA  000050    20                  RW,D,CON,LCL
$IDATA  000146    51                  RW,D,CON,LCL
$VARS   000634   206                  RW,D,CON,LCL
$TEMPS  000002     1                  RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 001014   518

.HONEYF=HONEYF
```

```
FORTRAN IV-PLUS V02-51          11:28:55    28-APR-78          PAGE 1
BUTTER.FTN      /TR:BLOCKS/WR

0001            DIMENSION IBUF(6),IPATE(2),ISB(2),H(30),Y(60)
        C
        C       THIS PROGRAM SYNTHESIZES AND EXECUTES
        C       AN INFINITE IMPULSE RESPONSE FILTER WITH COEFFICIENTS
        C       GENERATED BY THE MACFIL PROGRAM.  THE FILTERING LOOP
        C       IS FOR THE CASE WHERE THERE IS ONLY ONE NON-RECURSIVE
        C       WEIGHT AND FOUR RECURSIVE WEIGHTS.
        C
        C
        C       N IS THE NUMBER OF RECURSIVE WEIGHTS
0002            N=5
        C
        C
        C
        C       INITIALIZE DATA MATRIX FOR FILTER
0003            DO 299 I=1,N
0004            Y(I)=0.0
0005    299     CONTINUE
        C
        C       SET H COEFFICIENTS
0006            H(1)=.92476581
0007            H(2)=-.68534953
0008            H(3)=.30671978
0009            H(4)=-.77488319
0010            H(5)=.05301754
        C
        C
        C       SET G COEFFICIENT
0011            G=.522[illegible]
        C
        C       INITIALIZE [illegible] PERIPHERAL SYSTEM
0012            CALL ASLUN ( ,ISB)
        C
        C       DESIGNATE OUTPUT DAC CHANNEL FOR DATEL 256
0013            ICHAN=0
        C
        C       DESIGNATE REGISTER FOR LPS11 FLAG SET
0014            IEFN=7
        C
        C       SPECIFY TIME BETWEEN SAMPLES IN MILLISECONDS
0015            IRATE(2)=1
        C
        C       PUT LPS11 PTS ROUTINE IN MILLISECOND SAMPLING MODE
0016            IRATE(1)=3
        C
        C
        C       CALCULATE SAMPLE INTERVAL IN SECONDS
0017            ST=FLOAT(IPATE(2))/1000.
```

```
:ORTRAN IV-PLUS V02-51          11:28:55    28-APR-78          PAGE 2
:UTTER.FTN      /TP:BLOCKS/LP

        C
        C
3018    90      CALL RTS(IBUF,6,0,IRATE,IEFN,0,1,ISB)
3019            INDX=5
3020    10      CALL WAITFR(IEFN)
3021    15-     CALL CLREF(IEFN)
3022            SIGNA=IBUF(INDX)
        C
        C       SCALE IN VOLTS
3023            X=10000.*(SIGNA/2048.)-10000.

        C
        C
3024            SUM=0.0
3025            DO 20 I=1,N
3026            TERM=H(I)*Y(I)

3027            SUM=SUM +TERM
3028    20      CONTINUE
3029            Y(1)=TERM+S
3030            IDATA=Y(1)
        C
        C       SAVE RECURSIVE TERMS
3031            DO 544 I=1,N-1
3032            Y(I+1)=Y(I)
3033      544 CONTINUE
        C
        C       CALL LPS11 LED DISPLAY ROUTINE
3034            CALL LED(IDATA)
        C
        C       CALL ROUTINE TO OUTPUT RESULT TO DATEL 256
3035            CALL IDAC(ICHAN,IDATA)
        C
        C       ADJUST POINTERS FOR LPS11
        C       AND CLEAR HALF BUFFER FOR NEXT SAMPLE
3036            CALL  ADJLPS(IBUF,1)
        C
3037            INDX=INDX+1
        C
        C       CHECK STATUS REGISTER FOR PROPER I/O
        C       AND TERMINATE IF STATUS NOT CORRECT
3038            IF (INDX.GT.6) INDX=5
3039            IF (ISB(2).GE.1) GO TO 10
3040            IF (ISB(1).NE.0) GO TO 95
3041            GO TO 10
3042    95      CONTINUE
        C
        C       IF PROGRAM CRASHES PRINT STATUS ON WAY OUT
```

```
FORTRAN IV-PLUS V02-51          11:28:55    28-APR-78          PAGE 3
BUTTER.FTN      /TR:BLOCKS/WR

 0043           WRITE (5,200) ISB(1),ISB(2),IDATA,ISUF(INDX)
 0044     200   FORMAT(4I12)
 0045     195   CONTINUE
 0046           END


PROGRAM SECTIONS

 NAME        SIZE                    ATTRIBUTES

$CODE1   000716   231               RW,I,CON,LCL
$PDATA   000050    20               RW,D,CON,LCL
$IDATA   000060    24               RW,D,CON,LCL
$VARS    000640   208               RW,D,CON,LCL
$TEMPS   000002     1               RW,D,CON,LCL


TOTAL SPACE ALLOCATED = 001710   484

.BUTTER=BUTTER
```

APPENDIX H

The Datel 256 Driver Program: IDAC.MAC

The following assembly language program IDAC takes values from the filter execution progrsms (EASY, JUNK, and NINE) and writes the results to a digital to analog channel of the Datel 256 system. The call is:

```
CALL IDAC (ICHAN, IDATA)
```

where ICHAN is the channel number (0 to 15) and IDATA is the integer data (-2048 to +2048). The channel used now is 0, and the output pins are 12 = high and 11 = common. The channel or channels are addressed in the random mode.

```
        .TITLE  IDAC
IDAC::  MOV     (R5)+,R1                ;GET ARGUMENT FOR DAC
        MOVB    #20,@#160010            ;PUT IN RANDOM MODE
        MOV     @(R5)+,@#160012         ;SPECIFY CHANNEL 1
        MOV     @(R5)+,@#160014         ;WRITE VALUE TO DAC,START DAC
        RTS     PC
        .END
```

Program IDAC

The original program for the Datel 256 system is shown here only for the record. In order to do what needed to be done, the Datel had to be programmed to constantly switch between the block mode for the synchronous inputs and the register mode for the asynchronous outputs. For this reason, this plan was abandoned and the LPS11 system was used instead. The Datel 256 system is a good general purpose piece of equipment, but unfortunately, the particular interface to the pdp 11/45 is not particularly suitable for the digital filter task. At the time the Datel 256 system was originally purchased to work with the SEL810B or the HP2114B, it could not have been foreseen that its use in a closed loop system in conjunction with the pdp 11/45 would be so difficult.

However, since both the Datel 256 system and LPS11 system are available, it appears now that a suitable functional configuration can be obtained by using the LSP11 system with its ADC's and real-time clock for input, and the pdp 11/45 for processing, and the Datel 256 system for the DAC output. A signal flowchart of this configuration is shown in figure 4-1. The original code written to drive the Datel 256 system consisting of the following key instructions:

MOV #2000, R1	Load DMA memory start address into register 1
MOV #1, R2	Load word count into register 2

MOV #60,@#760010	Put into block mode and load status register 2
MOV #1000,@#760016	Put into block mode, and load starting and final addresses
MOV R1, @#760012	Load memory address registers
MOV R2,@#760014	Load word count and start block conversion

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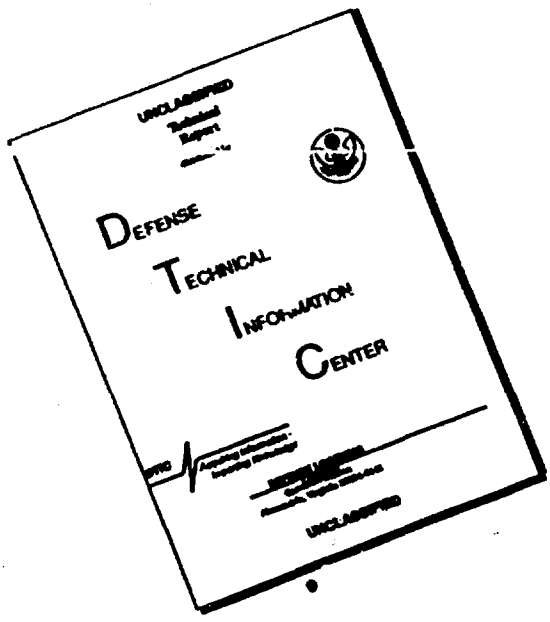

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